

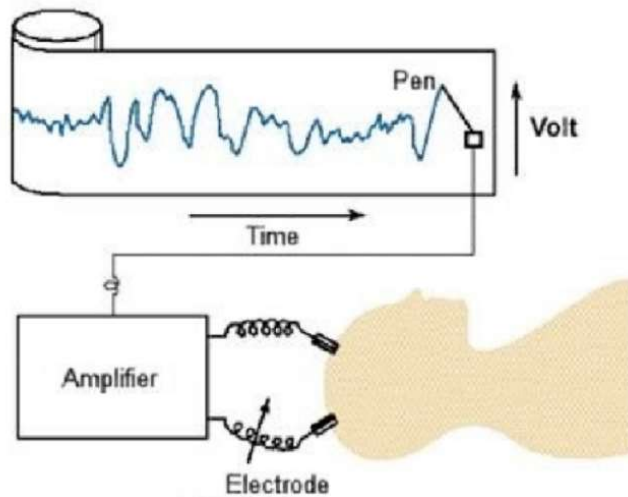
Using Multivariate Pattern Analysis (MVPA) in EEG

July 2024

Outlines

1. EEG background
 - Traditional univariate ERP analysis
 - Drawback of univariate ERP analysis
2. Introduce Multivariate Pattern Analysis (MVPA)
 - Advantage of MVPA
 - MVPA approaches
3. My work using MVPA in N-back EEG study
4. Summary

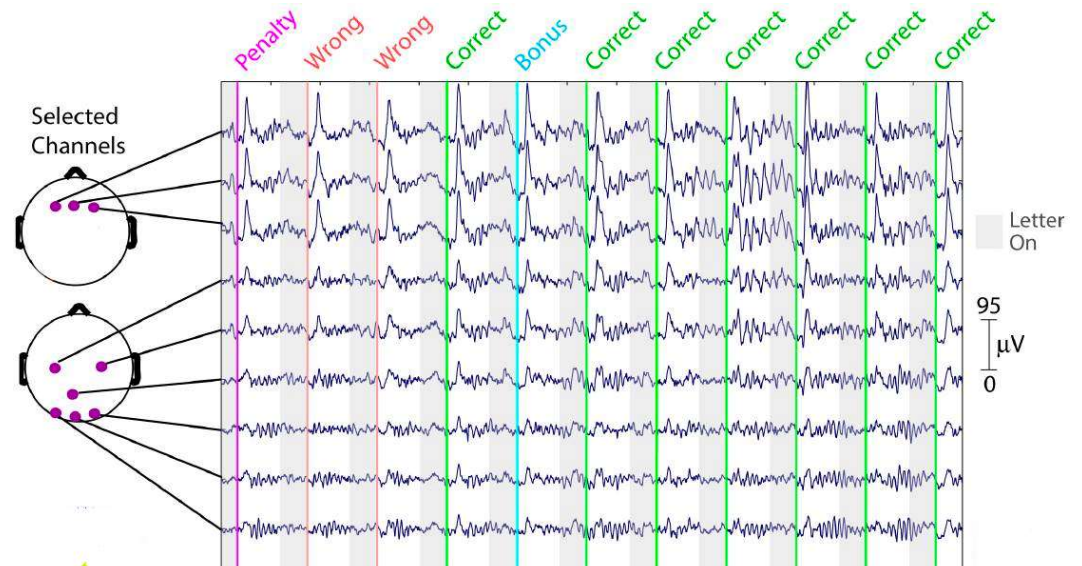
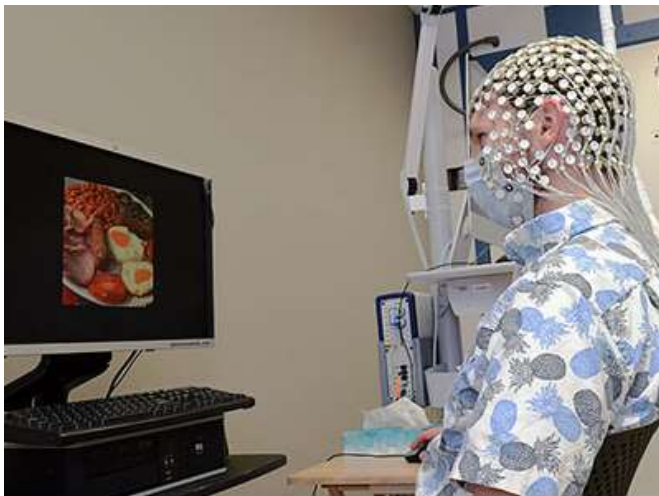
EEG background



- Measure volt difference between electrode/channel and reference on the scalp
- Offer millisecond temporal resolution of how activity patterns emerge and evolve
- Low cost, easy to collect brain signals, low spatial resolution

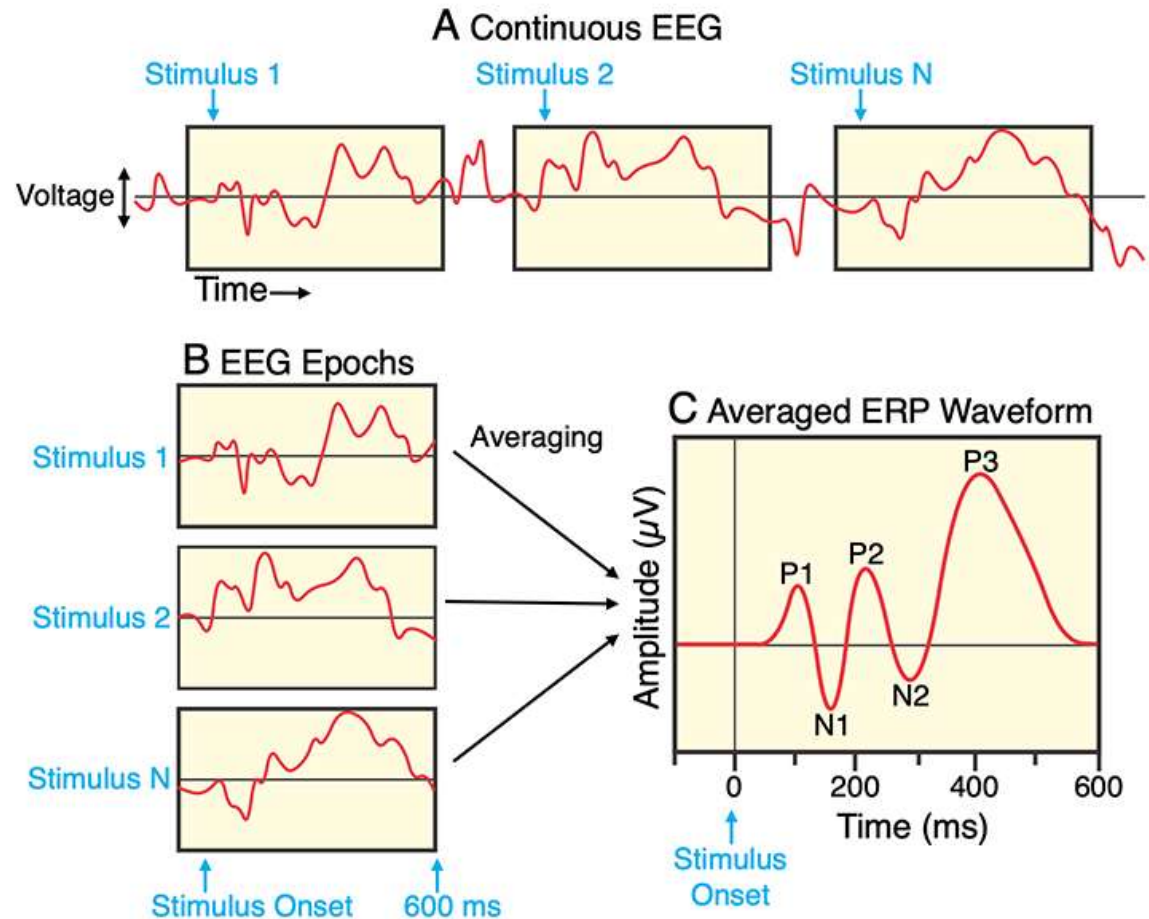
EEG background

- The signal in each of the channels can be plotted over time, as can be seen in an event related potential (ERP).



Traditional univariate ERP analysis

- Extract components/features on averaged waveform on a selected channel
- Features/measures: channel, amplitude(intensity), latency, power spectrum, Time-frequency representations

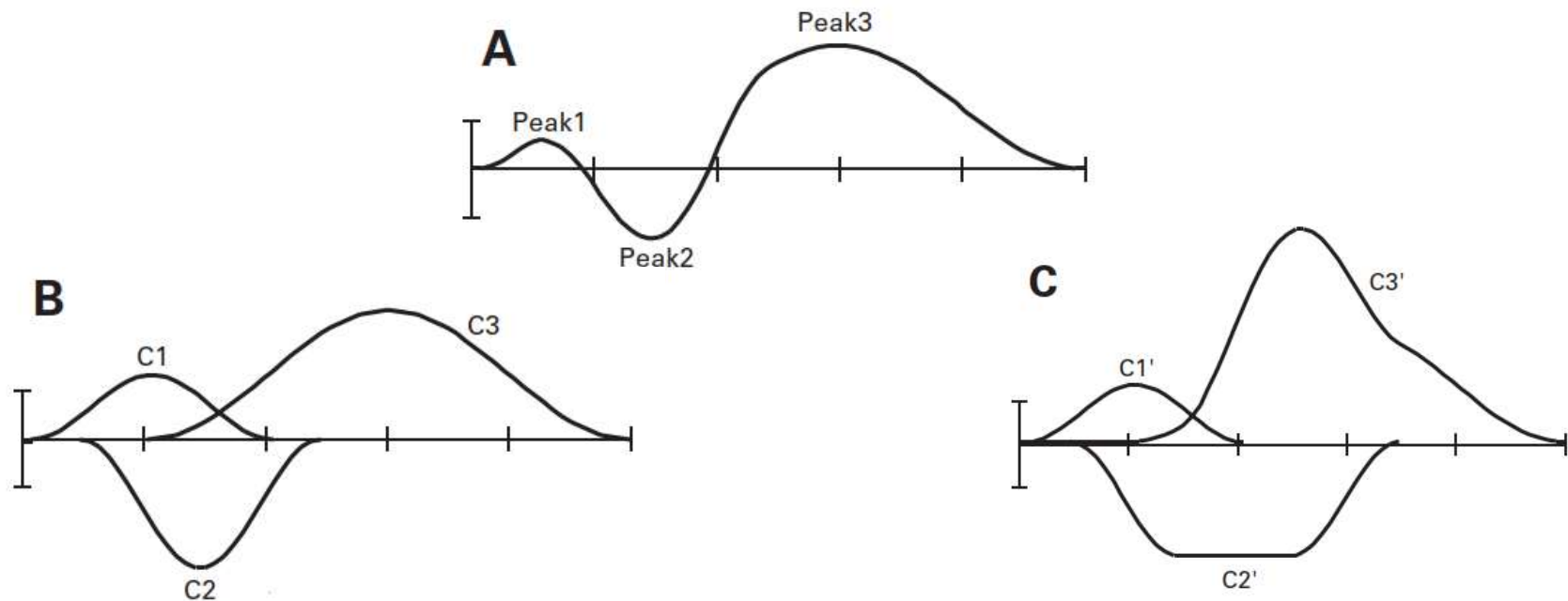


Problems with univariate ERP analysis

1. Do the analyses on a predefined brain region / channels / frequency /time
2. Average multiple trials EEG signal to get ERP

Problems with univariate ERP analysis

- The average ERP waveform doesn't always represent the underlying single channel activities



Introduction to MVPA

- MVPA includes a number of related multivariate analytical techniques, compared to classical univariate ERP analysis.
- To identify whether patterns of activation across the brain are different between experimental conditions, categories of stimuli, or participant's phenotype (even when specific ERPs would look highly similar)

Advantages of MVPA

- Using MVPA, you do not have to specify or know beforehand which electrodes contain the experimental effect, especially when the locus of the effect is unknown
- MVPA can analyze single trial data or averaged data
- MVPA can analyze multiple features at one time, which simplifies the multiple comparisons problem

MVPA – Two approaches

There are two main approaches of MVPA:

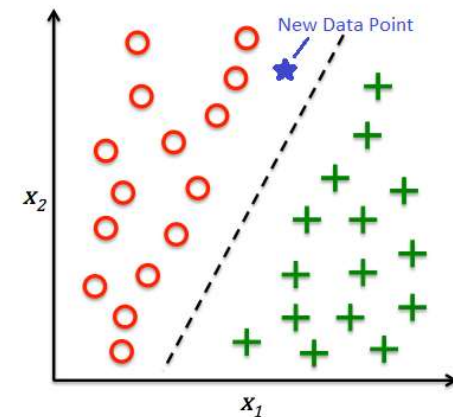
- 1) Classifiers: classifications / decoding
- 2) Similarity : Representational Similarity Analysis (RSA, similarity) or Representational Dissimilarity Analysis (RDA, 1- similarity)

MVPA – classification approach

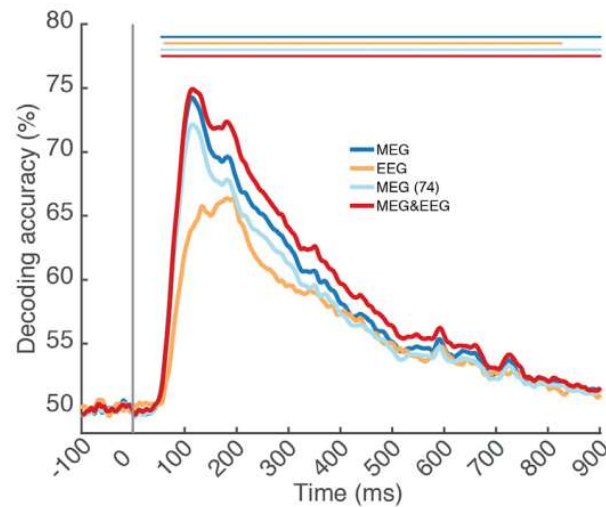
- Classifier / model
- Features / data
- Classes / labels
- Two classes / multiple classes
- Decision boundary / surface
- Train-test algorithms (e.g. LDA, SVM, RF, ANN)
- K-fold Cross-validation/separate training set



- Accuracy / AUC / F1-score

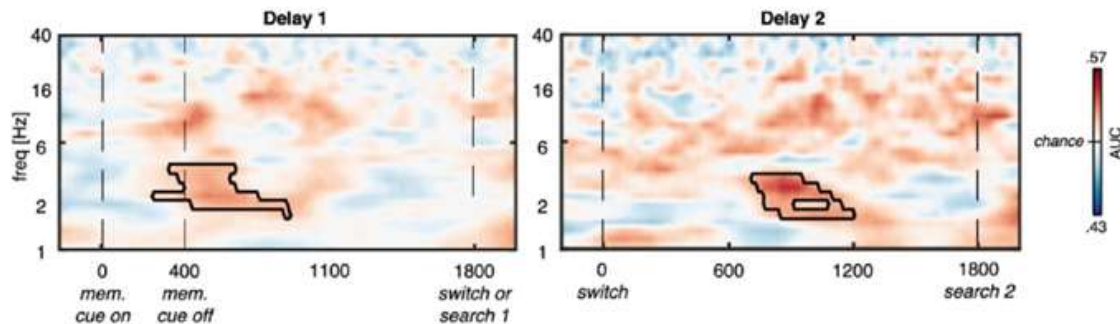


MVPA classification applications – 1



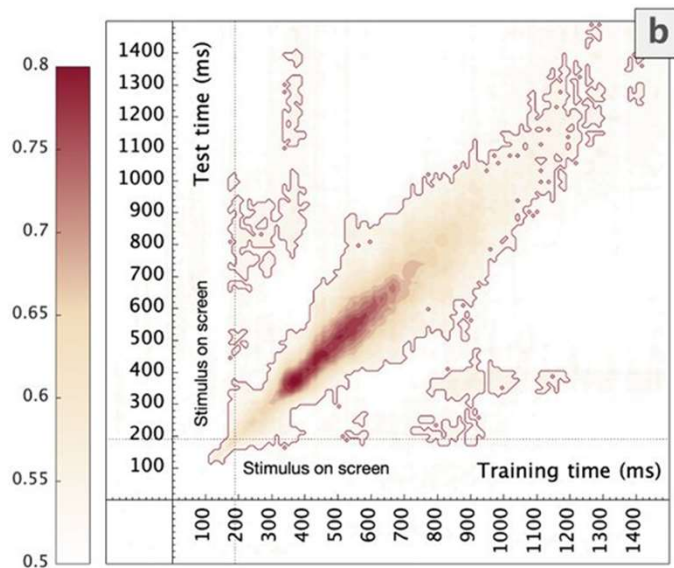
- Temporally and spatially-unconstrained, overall accuracy

A Classifier accuracy for time-frequency power



- Time-frequency power

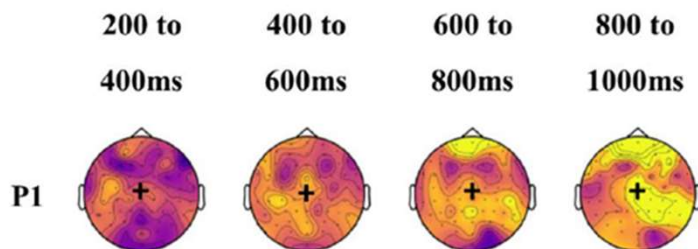
MVPA classification applications - 2



- Temporal generalization

congruent and incongruent task

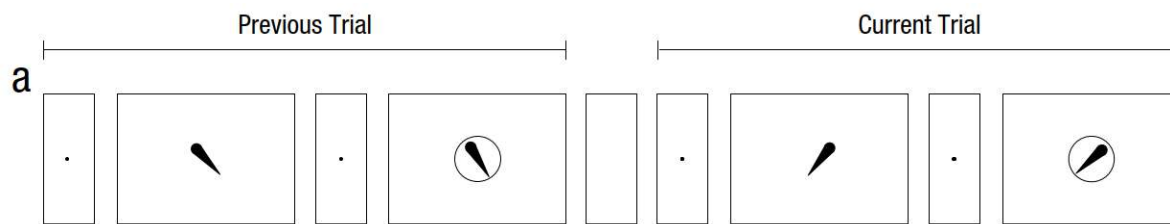
target processing reappears after the behavioral response



- Time–space-resolved, accuracy on scalp map with time

MVPA classification applications - 3

- Serial dependence (Tracking memory over time)



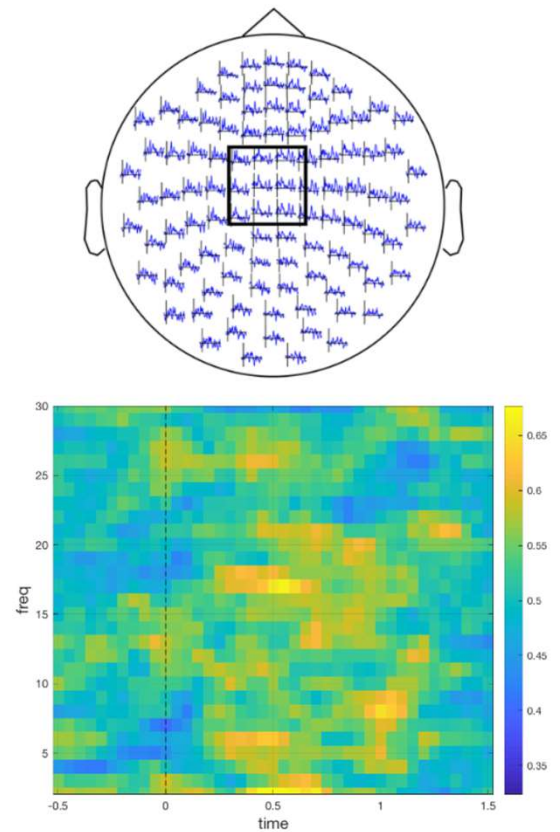
- The previous 1 trial can be decoded from current trial even when previous one is irrelevant to the current.
- But previous 2 trial cannot be decoded from current trial.

1. Past experiences influence the processing of new information
2. The presentation of the current-trial sample stimulus reactivated or boosted a representation of the previous trial stimulus

MVPA classification applications - Searchlight

Aim: Discriminating patterns that are potentially spread out across the whole brain

- Sliding a window throughout the whole brain and performing independent decoding analyses within each region.
- Searchlight analysis is not limited to spatial coordinates. The same idea can be applied to other dimensions such as time points and frequencies.



MVPA – RSA/RDA analysis

- Neurons within a brain region jointly represent information about a stimuli in a specific population code, or pattern of activity
- RSA/RDA provide ways to map brain to brain, or brain to behavior, or data from different imaging sources

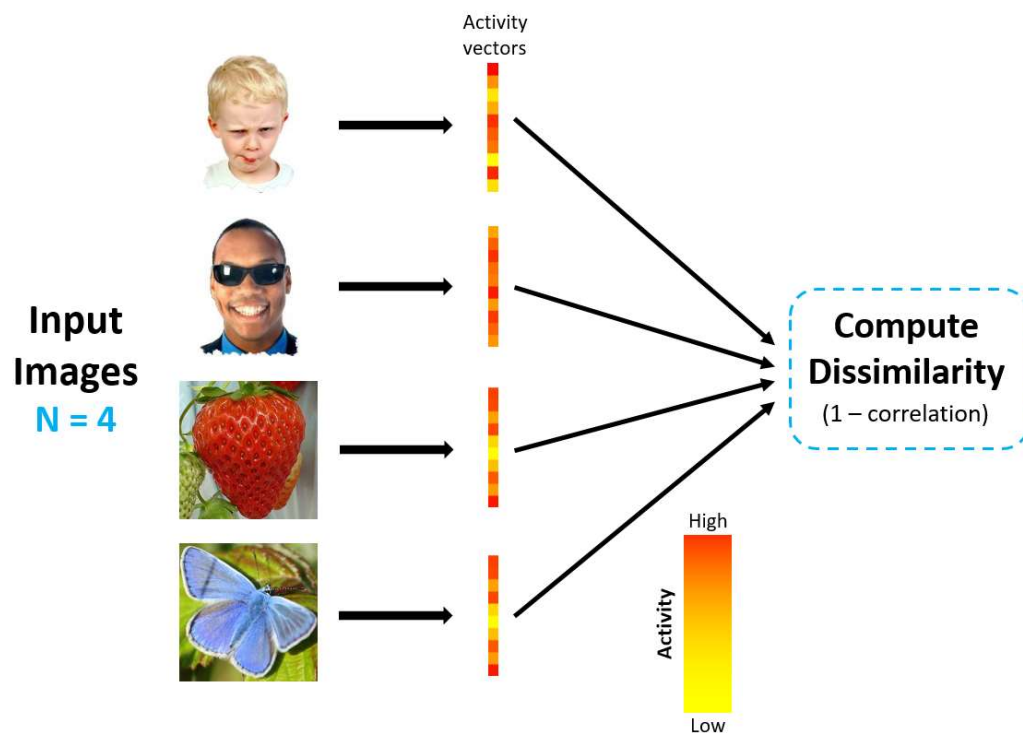
RSA/RDA implementations

- Comparisons of spatial patterns across conditions/groups can be represented either in terms of the similarity of the activity patterns (r) or the dissimilarity ($1-r$).
- Similarity metrics:
 1. Distances: Euclidean distance, Mahalanobis distance, and cross-validated Mahalanobis or "crossnobis" distance.
 2. Correlations: Kendall's rank correlation, Pearson correlation, Spearman's rank correlation
- Representational dissimilarity matrix (RDM) or Representational similarity matrix (RSM)

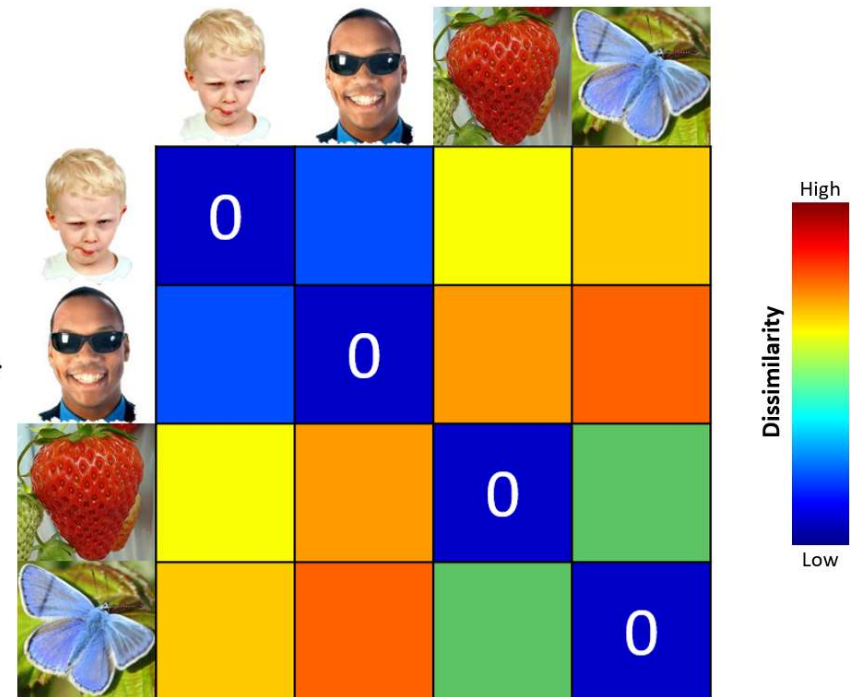
RDA - Representational Dissimilarity Matrices (RDM)

Representational Pattern

e.g. Activity from neurons, model units, or voxels
recorded in vector format

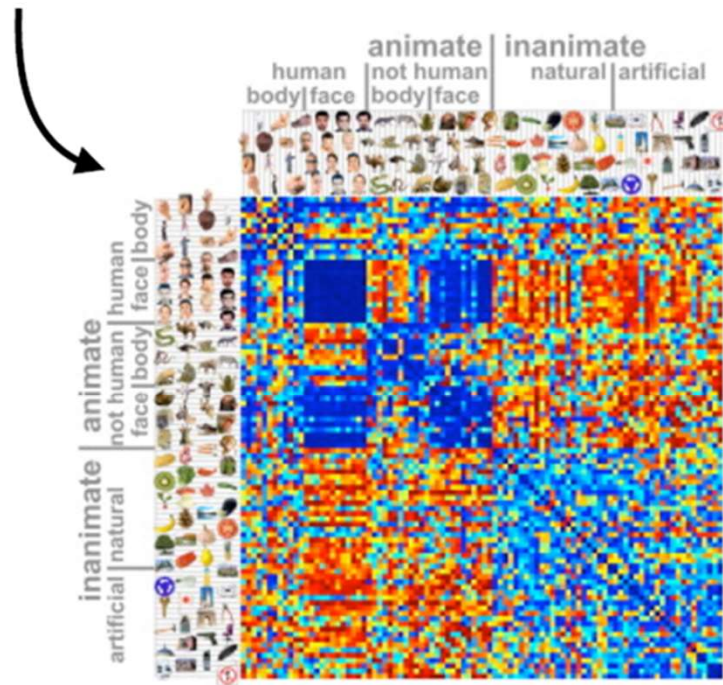


$N \times N$ Representational Dissimilarity Matrix (RDM)

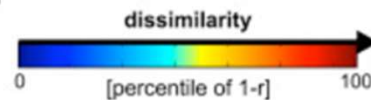


RSA - Across species and experiments

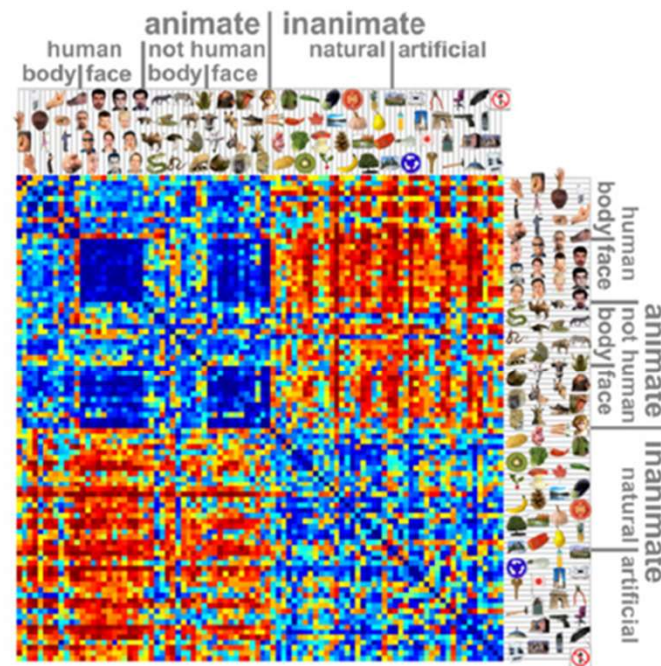
neurophysiology



monkey IT

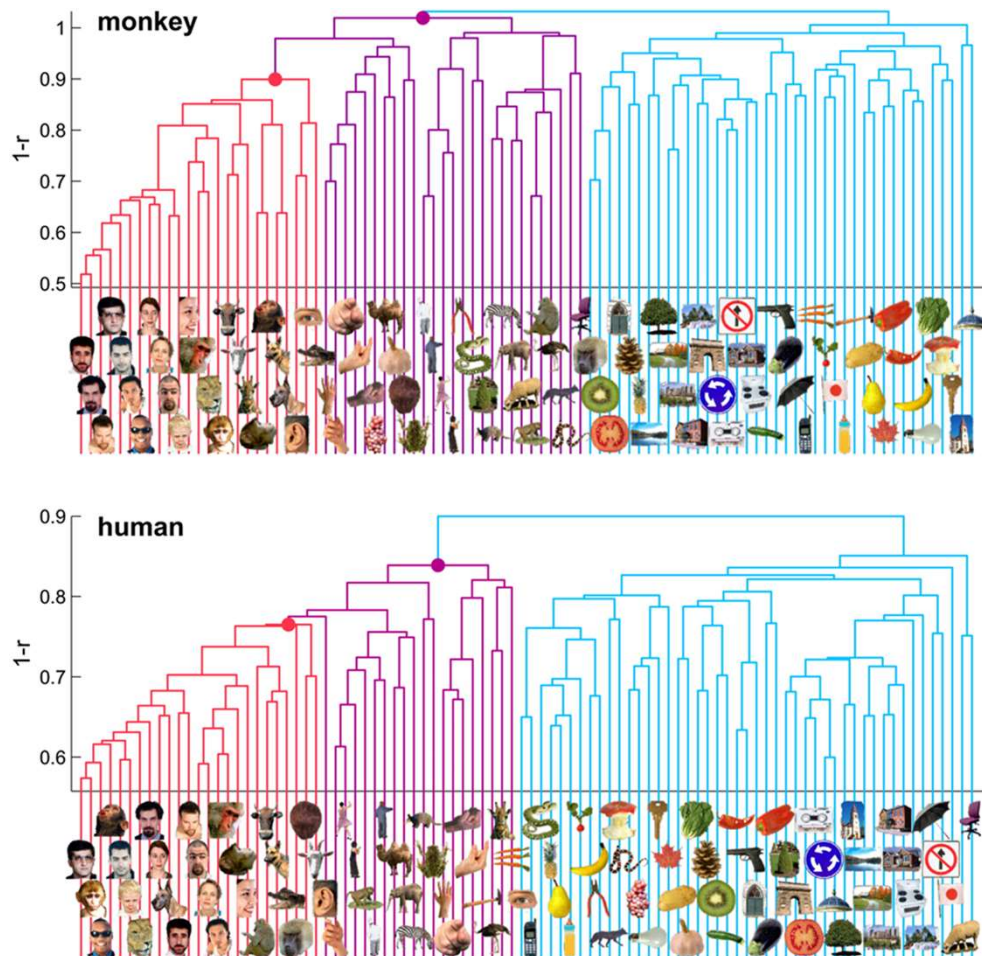


fMRI



human IT

RSA - Dendrogram

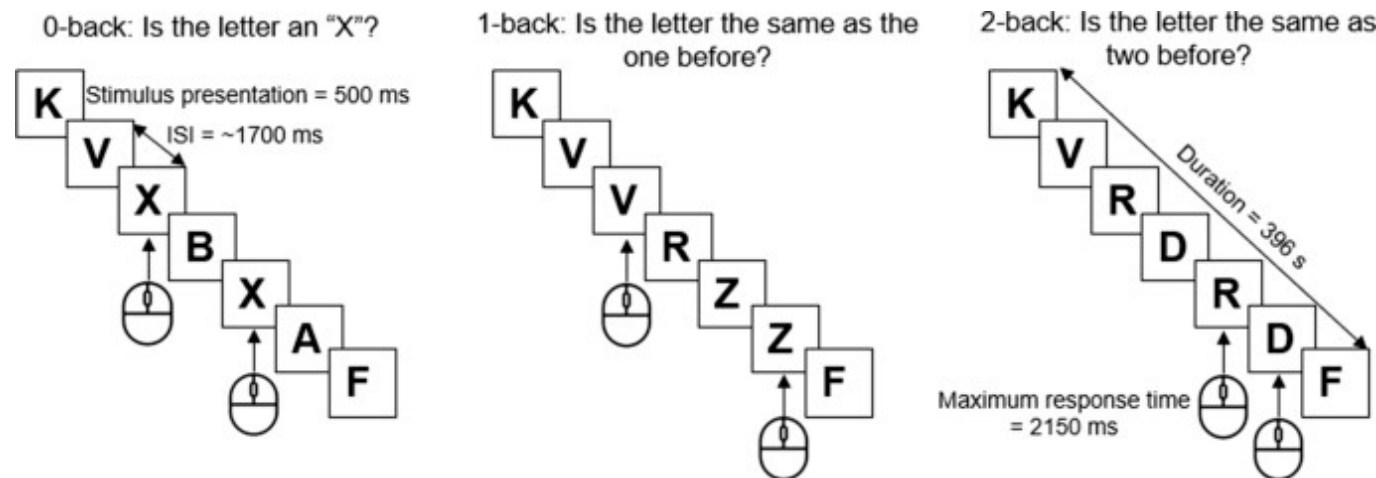


- Hierarchical clustering (dendrogram) based on the representational dissimilarity matrix enables comparison between representations across species

Kriegeskorte et al Neuron 2008

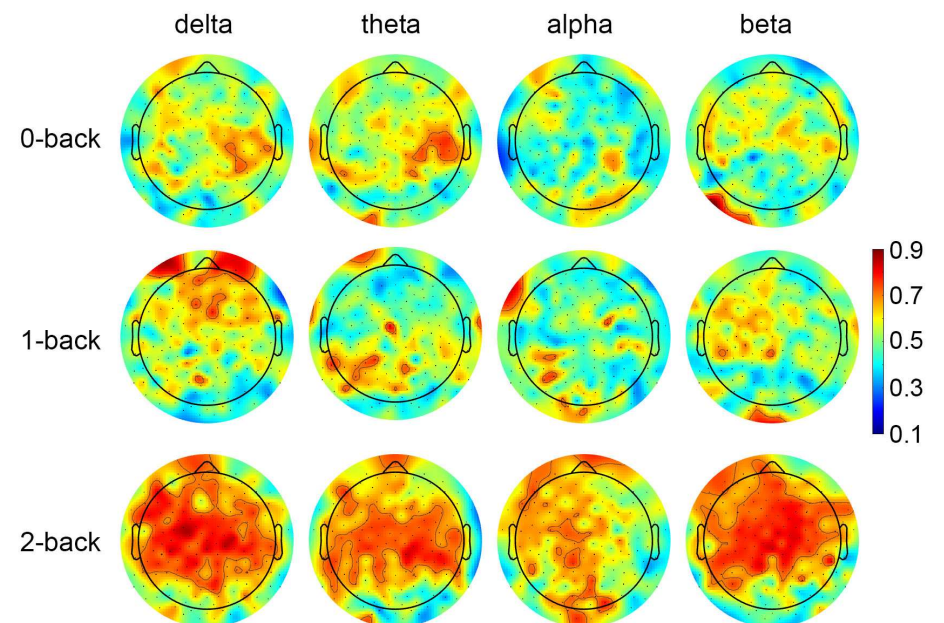
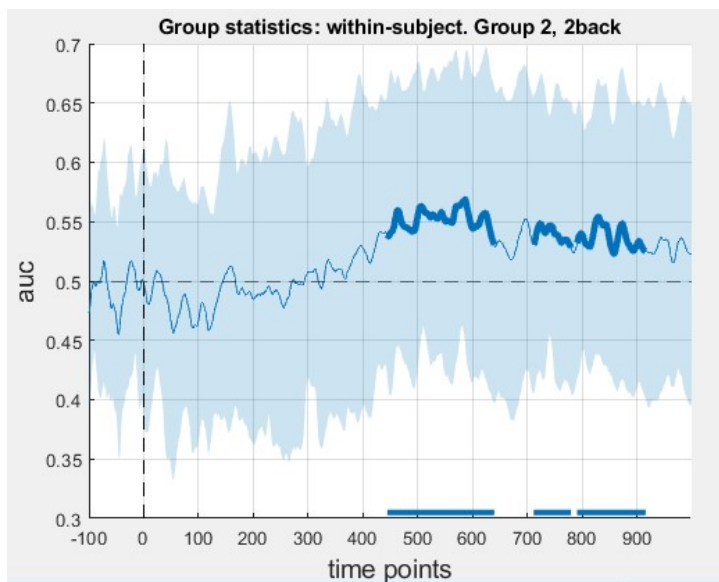
My work in N-back EEG

- 3 groups: healthy old (#21), preclinical AD(#22), MCI(#29)
- 3 visits: baseline, 1 year, 2 year
- N-back EEG task: 0, 1, 2 back; target, non-target



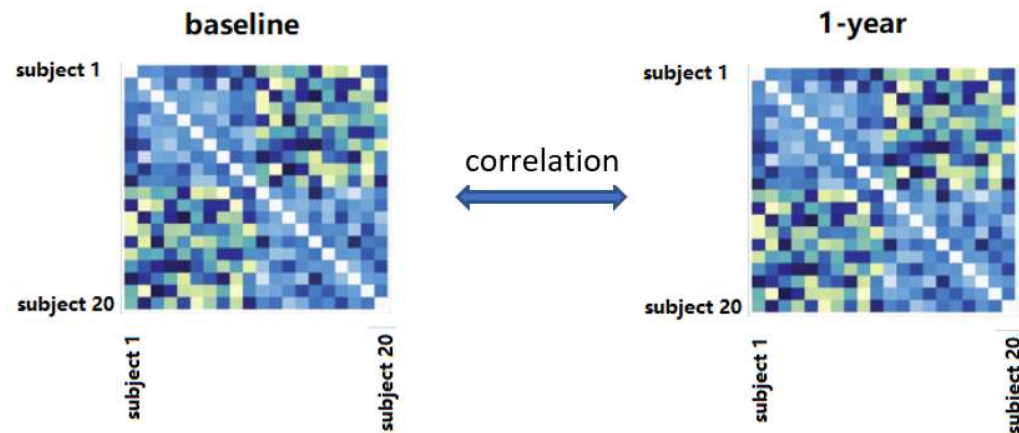
Devos, H. EEG/ERP evidence of possible hyperexcitability in older adults with elevated beta-amyloid. *Transl Neurodegener* (2022).

Results - classification



nontarget condition, 2-back tasks ,
preclinical AD vs controls

RSA – longitudinal baseline vs 1-year



Expectation: healthy group is similar (significant) between baseline and 1 year EEG. MCI is dissimilar (not significant).

- Step 1: Calculate pairwise correlation (ERPs on 15 channels, using Pearson correlation) between every two subjects in baseline and 1-year separately (within each group, within each n-back task, within visit). Get baseline and 1-year RDM matrix.
- Step 2: Test the relatedness of the baseline RDM to 1-year RDM (between visit) by randomising the subjects of the baseline RDM. The Pearson correlation is used. Get the p-value and r correlation coefficients.

Summary

- MVPA is an analyzing approach to extend the traditional univariate ERP analysis
- MVPA allows you to find effects without selecting electrodes/time windows
- MVPA identifies differences that are not picked up by a regular ERP analysis

Reference

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- https://www.fahrenfort.com/EPOS_course/Day2.pdf
- [free EEG data database freely ERP data publicly available \(ucsd.edu\)](#)
- [RSA – Algonauts Project 2019 \(mit.edu\)](#)
- doi:10.1142/S0129065720500240
- <https://erpinfo.org/blog/2022/1/20/rsa>
- Other online materials