Single trial analysis using non-negative matrix factorizations

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MAX

Introduction

The reaction to a stimulus may differ across trials of the same stimulus type.

For instance, the stimuli may consist of sentences that evoke different reactions depending on their content. If those reactions are not predictable then the differences between trials cannot be described by the experimental design. Rather, they can only be inferred by differences in the BOLD responses that they evoke.

Idea:

- 1. Use a new matrix decomposition method (NMF) to uncover such hidden structure in the data.
- 2. Use the NMF decomposition to investigate the interaction between trials in across different brain regions.

NMF decompositions

Consider an experimental setup in which one or more stimuli are presented repeatedly and in a possibly randomized order. We assume that *m* trials of the same event type are given. The m trial vectors of length n form the columns of the input matrix V. Non-negative matrix factorization (NMF) produces a decomposition of the form



In our context, typical values are m=40 (number of trials) n=12 (number of timesteps per trial), and r=3 (number of basis functions).

The Algorithm

The algorithm for obtaining an NMF decomposition ([2]):

$$H_{a\mu} \leftarrow H_{a\mu} \frac{(W^T V)_{a\mu}}{(W^T W H)_{a\mu}}$$
$$W_{ia} \leftarrow W_{ia} \frac{(V H^T)_{ia}}{(W H H^T)_{ia}}$$

Synthetic Data



Application to single trial data



Activation map of the fMRI experiment by Volz et al.[1]. The single trial data were obtained from voxels in the anterior frontomedian cortex (aFMC) and the precuneus (PCU).

- In this experiments, participants were presented with two city names and had to indicate which city they thought was larger.
- If a subject recognizes the city name he/she is more likely to think that it is large (``recognition heuristic").
- Since we cannot know which heuristic or strategy a subject employs in each trial there may be hidden information in the single trial data.



Single trial data in aFMC of one subject, before and after application of NMF.



A synthetically generated





REFERENCES

[1]Volz, et al. (in press), Why you think Milan is larger than Modena: The neural correlates of the recognition heuristic, J Cogn Neurosci [2] Lee & Seung (1999), Learning the parts of objects by non-negative matrix factorization, Nature, 401:788-791

Comparisons of trials between brain regions aFMC (red) and PCU (blue) averaged across 12 subjects. The thick lines show averages, the thin lines the corresponding standard errors based on the inter-subject variance.



- We found that NMF may help to uncover hidden structure in single trial data. In the fMRI ٠ data reported here, three clusters of trials were found.
- We found that the city recognition value correlated with cluster membership so that we can assume that the decomposition revealed meaningful information.
- We also found that a low recognition value correlated with a deactivation in aFMC. A possible interpretation might be that a deactivation of the Recognition Heuristic leads to a suppression of the default mode network.