Coupled generator decomposition for fusion of electro- and magnetoencephalography data

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Looking for PostDoc positions/collabs!
As of Dec 2024 (remote?)
- Unsupervised ML & functional neuroimaging
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Resume

- Data fusion can identify common features across diverse data sources, e.g., subjects or modalities, while accounting for data source-specific variability.
- Here we introduce the concept of *coupled generator decomposition* and demonstrate how it generalizes sparse principal component analysis for data fusion in a time-locked EEG/MEG face perception study.
- For data fusion, a source matrix $\boldsymbol{G}$ is shared across data sources, while mixing matrices $\boldsymbol{S}^{(m,b)}$ for modality m and subject b allow for differing source activation profile.
- Our models reveal altered ~170ms fusiform face area activation for scrambled faces as opposed to real faces, particularly evident in the multimodal, multisubject model as opposed to a group model.

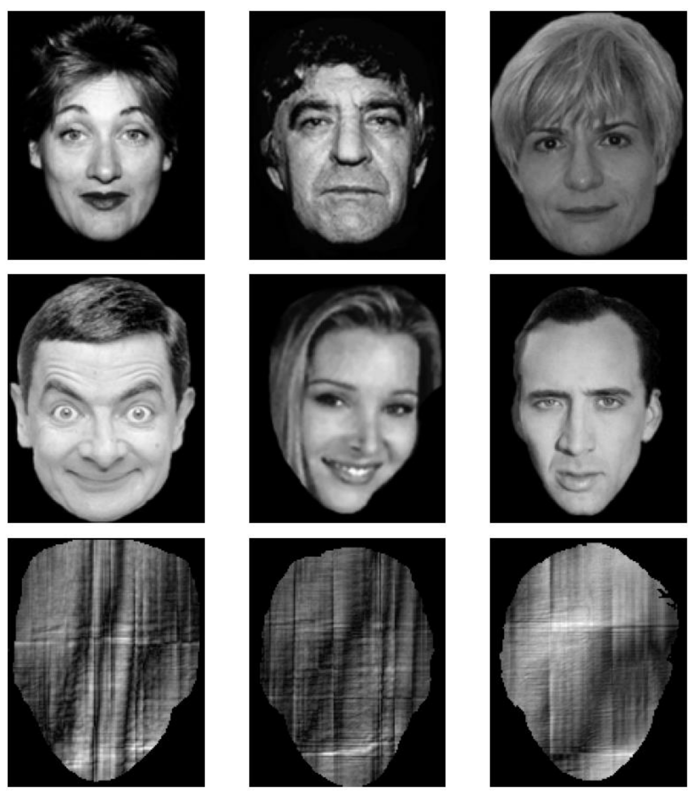
Model

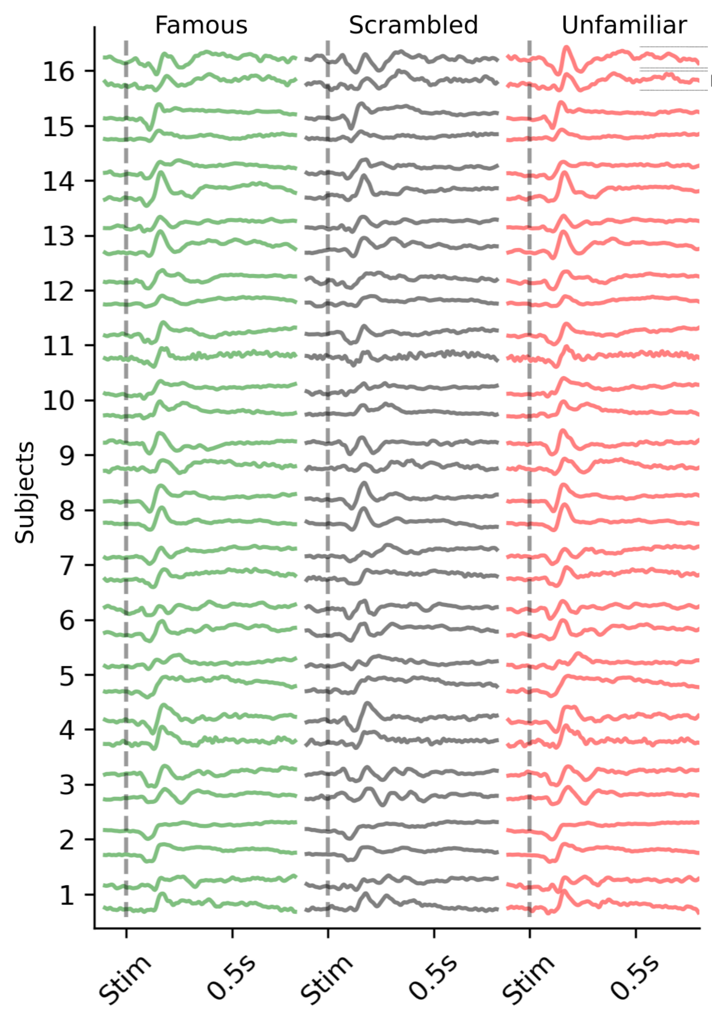
$$\underset{\mathbf{G},\mathbf{S}}{\operatorname{argmin}} \sum_{b}^{B} \sum_{m}^{M} \left|\left|\boldsymbol{X}^{(m,b)} - \widetilde{\boldsymbol{X}}^{(m,b)} \boldsymbol{G} \boldsymbol{S}^{(m,b)}\right|\right|_F^2 + \lambda_2 \sum_{k=1}^{K} \left|\left|\boldsymbol{G}_k\right|\right|_2^2 + \lambda_1 \sum_{k=1}^{K} \left|\left|\boldsymbol{G}_k\right|\right|_1$$

- $\widetilde{\boldsymbol{X}}$ may be an altered version of $\boldsymbol{X}$ that sources are learned from, e.g., the poststimulus part of the data.
- $\boldsymbol{G}$ is learned via stochastic optimization in PyTorch (learning rate 0.01).
- $\boldsymbol{S}$ is inferred via a Procustes transformation:
  $(\boldsymbol{X}^T\boldsymbol{X})\boldsymbol{G} = \boldsymbol{U\Sigma V}^T$
  $\boldsymbol{S}^T = \boldsymbol{UV}^T$

PyTorch toolbox available here
Includes coupled generator decomposition using sparse PCA and archetypal analysis

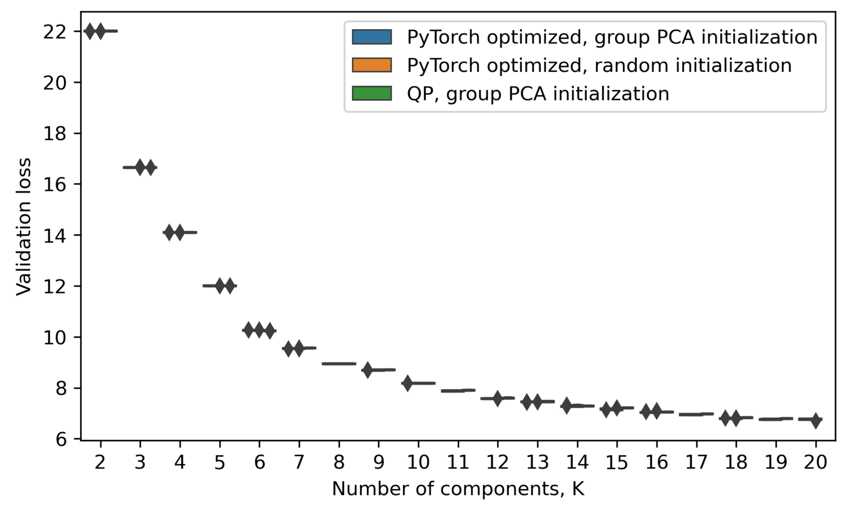
Time-locked face perception data set [1]

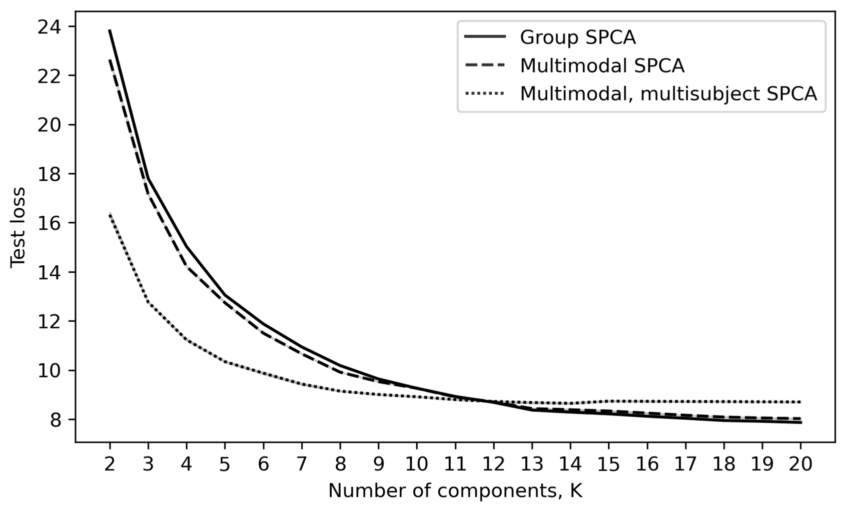




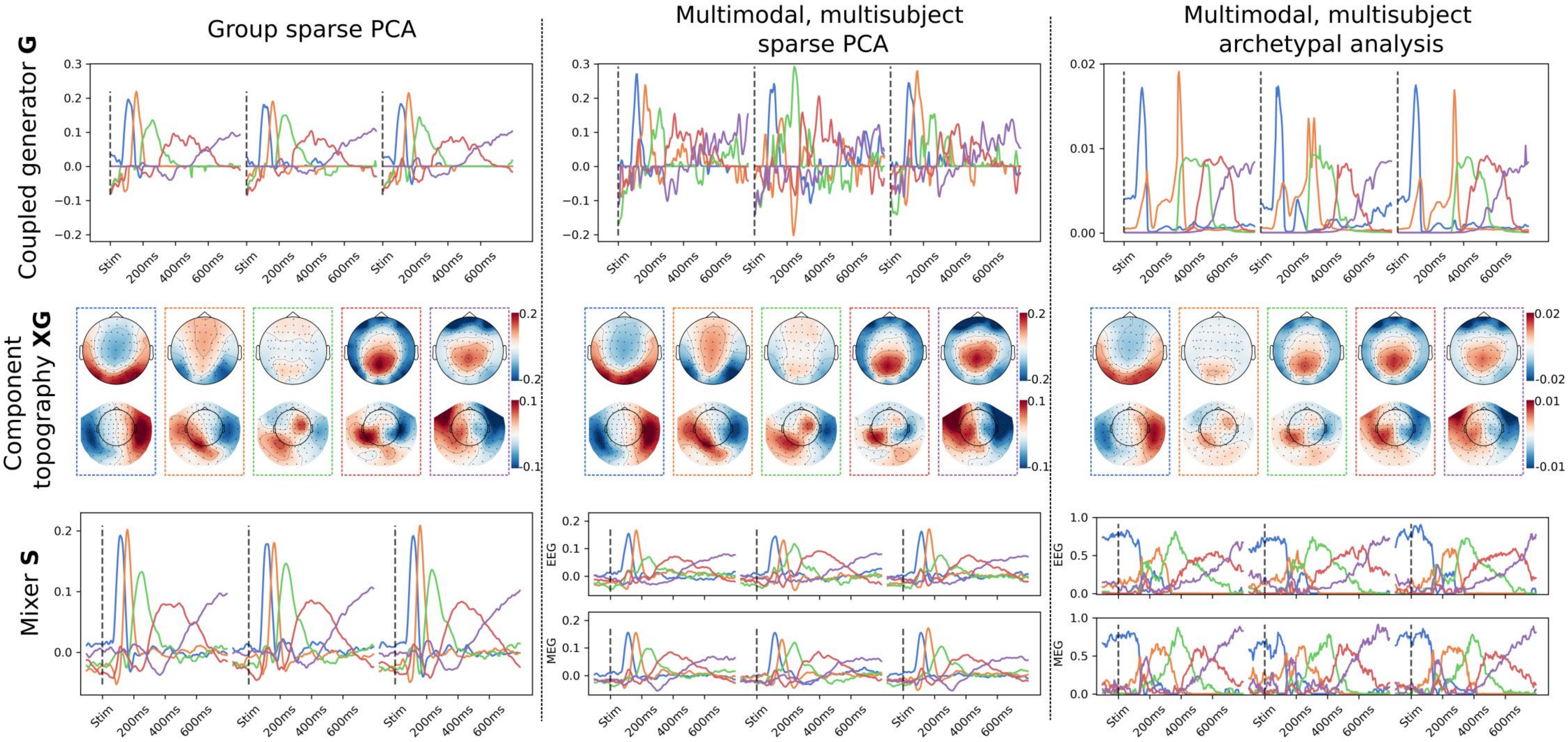
Model estimation

K	Group λ_1	Group λ_2	Multimodal λ_1	Multimodal λ_2	MMMS λ_1	MMMS λ_2
2	10^{-4}	10^{-4}	10^{-4}	10^{-2}	10^{-5}	10^{-4}
3	10^{-3}	10^{-1}	10^{-4}	0	10^{-4}	10^{-4}
4	10^{-5}	10^{-1}	0	0	10^{-2}	10^{-5}
5	10^{-3}	10^{-1}	10^{-5}	0	10^{-2}	10^{-1}
6	10^{-2}	10^{-2}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
7	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
8	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
9	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
10	10^{-2}	10^{-1}	10^{-3}	10^{-1}	10^{-2}	10^{-1}
11	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-1}	10^{-1}
12	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-1}	10^{-1}
13	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-1}	10^{-1}
14	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-1}	10^{-1}
15	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
16	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
17	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
18	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
19	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
20	10^{-2}	10^{-1}	10^{-2}	10^{-1}	10^{-2}	10^{-1}





Results



References
[1] *A multi-subject, multi-modal human neuroimaging dataset*, Wakeman DG & Henson RN, Scientific Data (2015)