ECML–PKDD 2016 RIVA DEL GARDA

UIC

Semi-supervised Tensor Factorization for Brain Network Analysis

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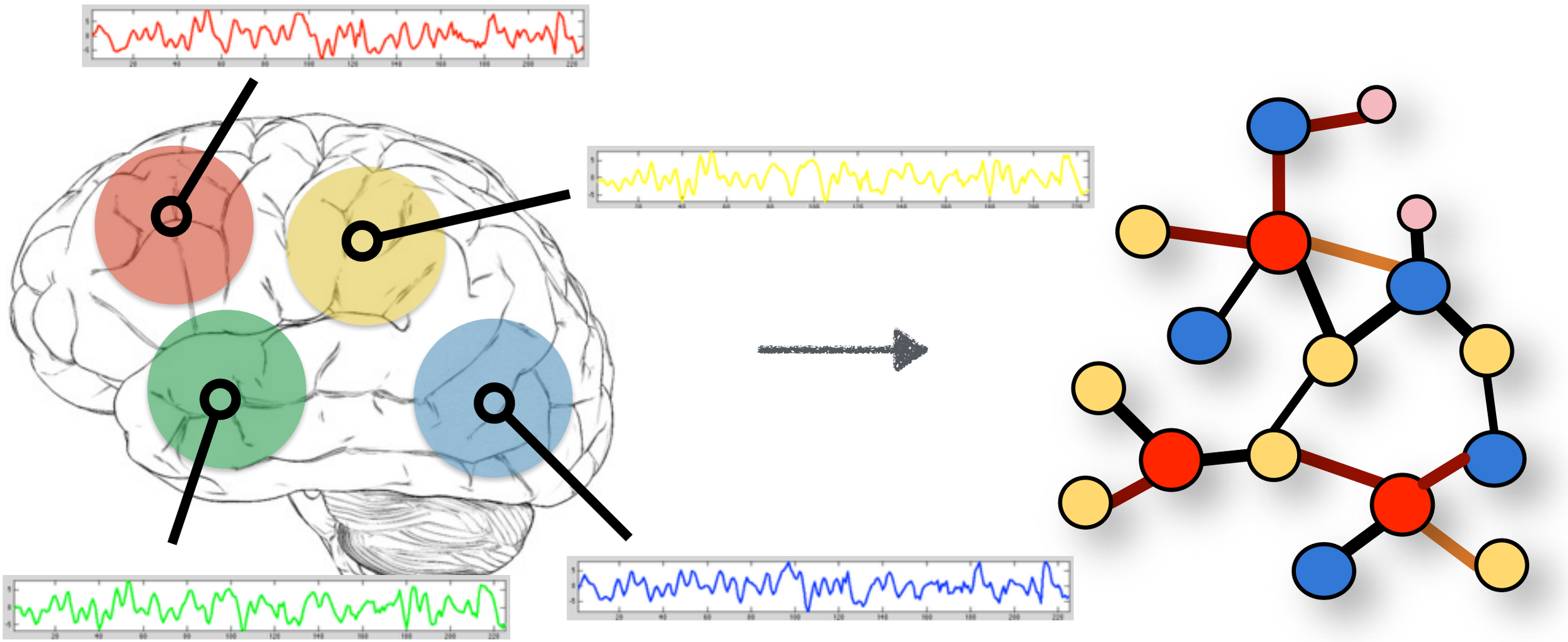
Brain Network Data

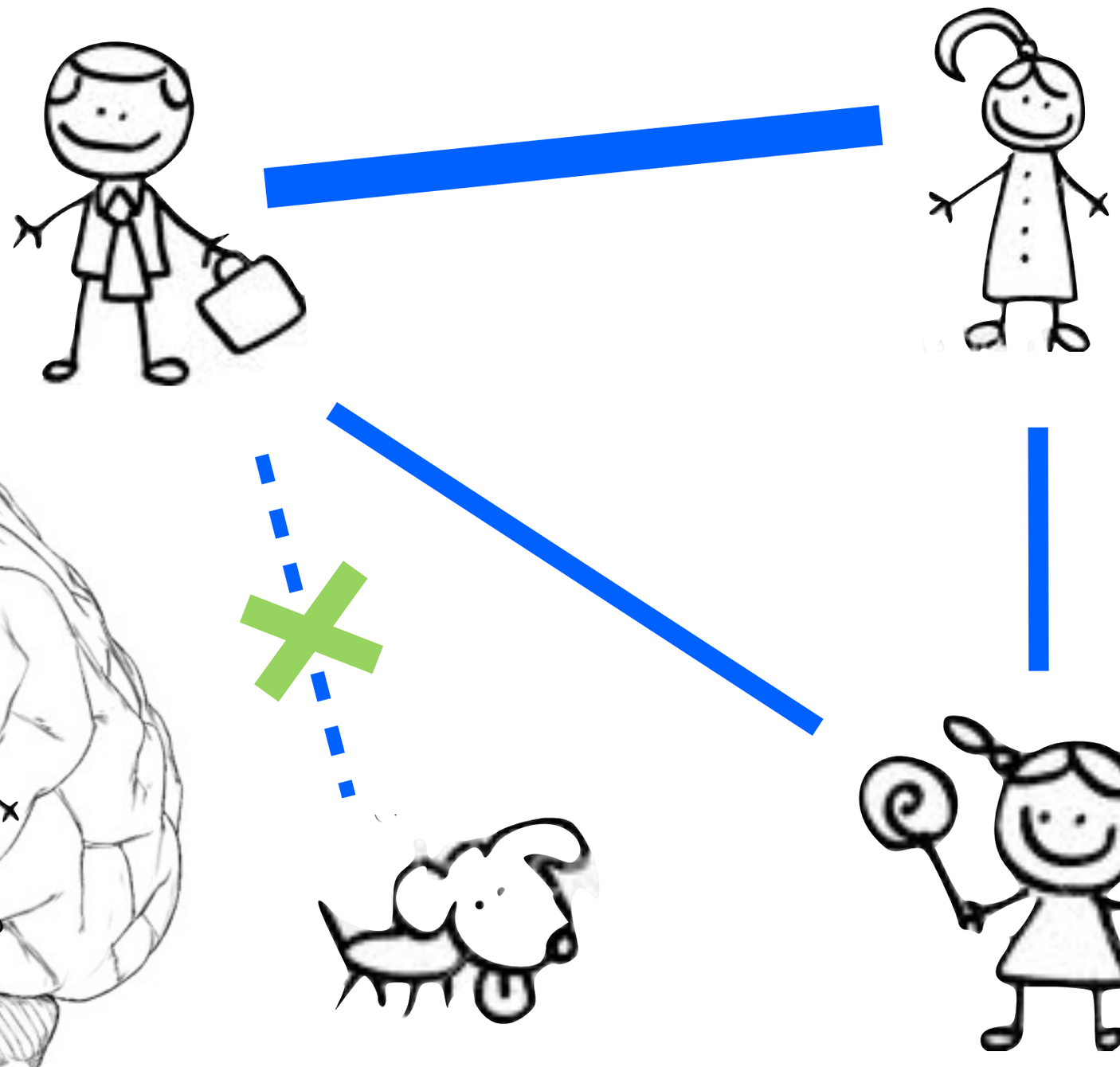


Neuroimaging

Brain Networks

Brain Network Data

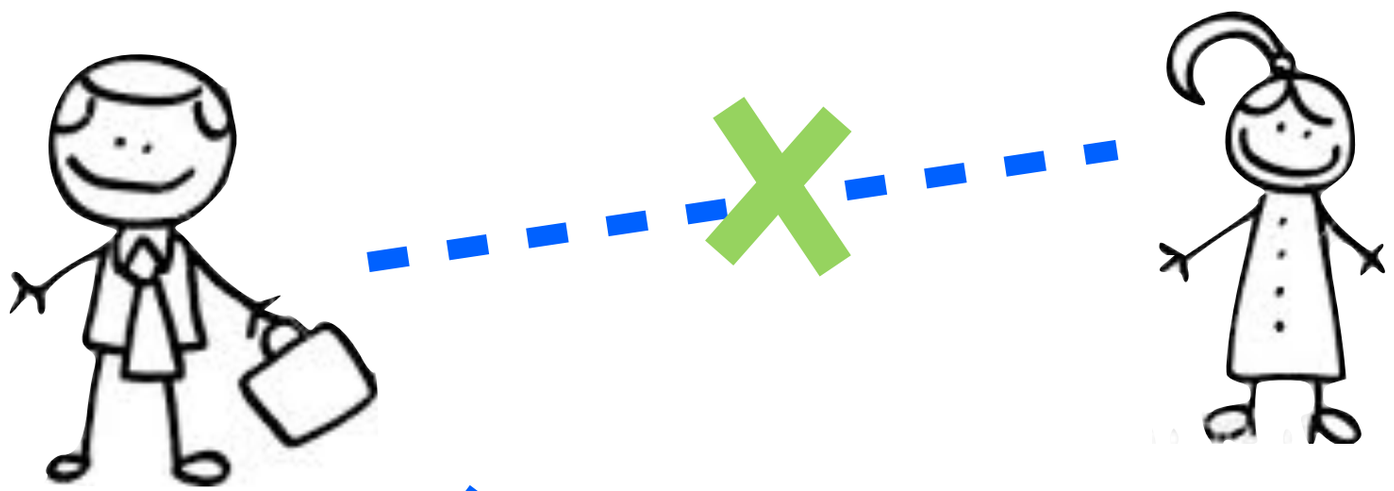
healthy brain



Good family

Brain Network Data

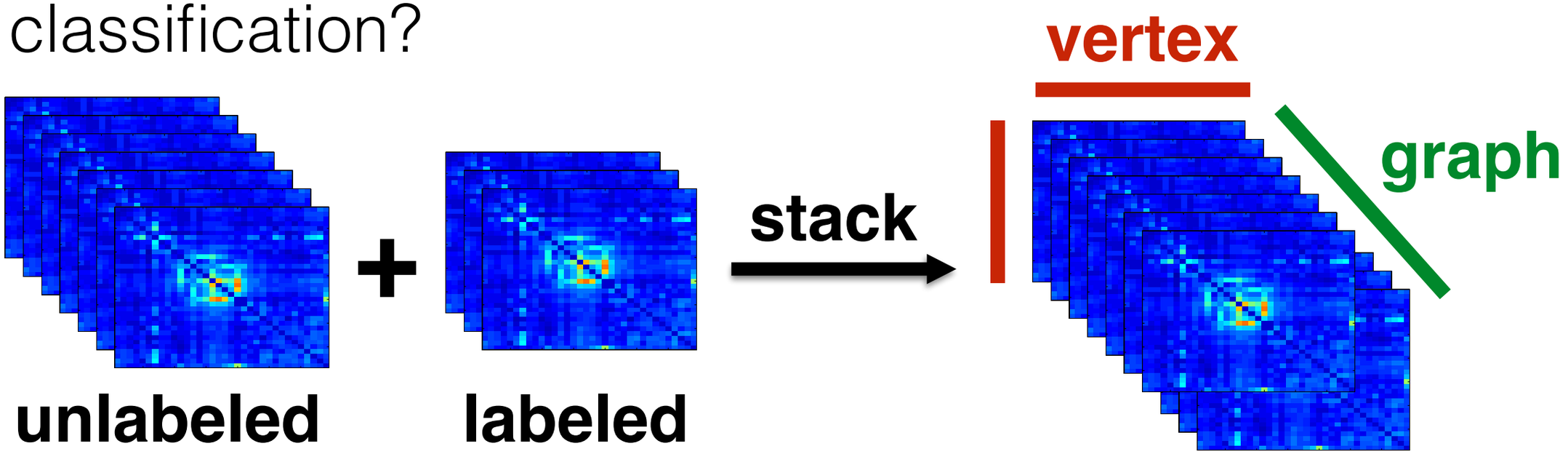
diseased brain



Connectivity problem

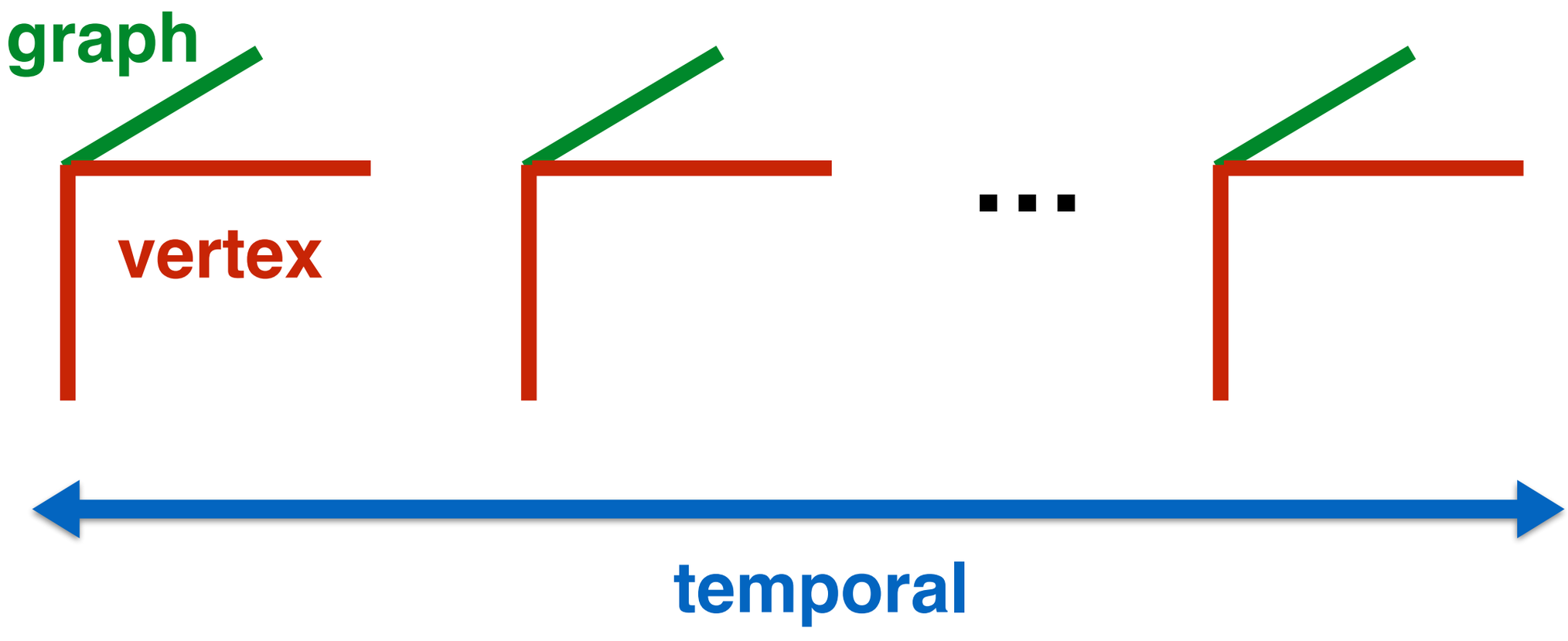
Problems & Solutions

- (P1) How can we leverage the unlabeled data, i.e., resting-state brain networks, to facilitate classification?



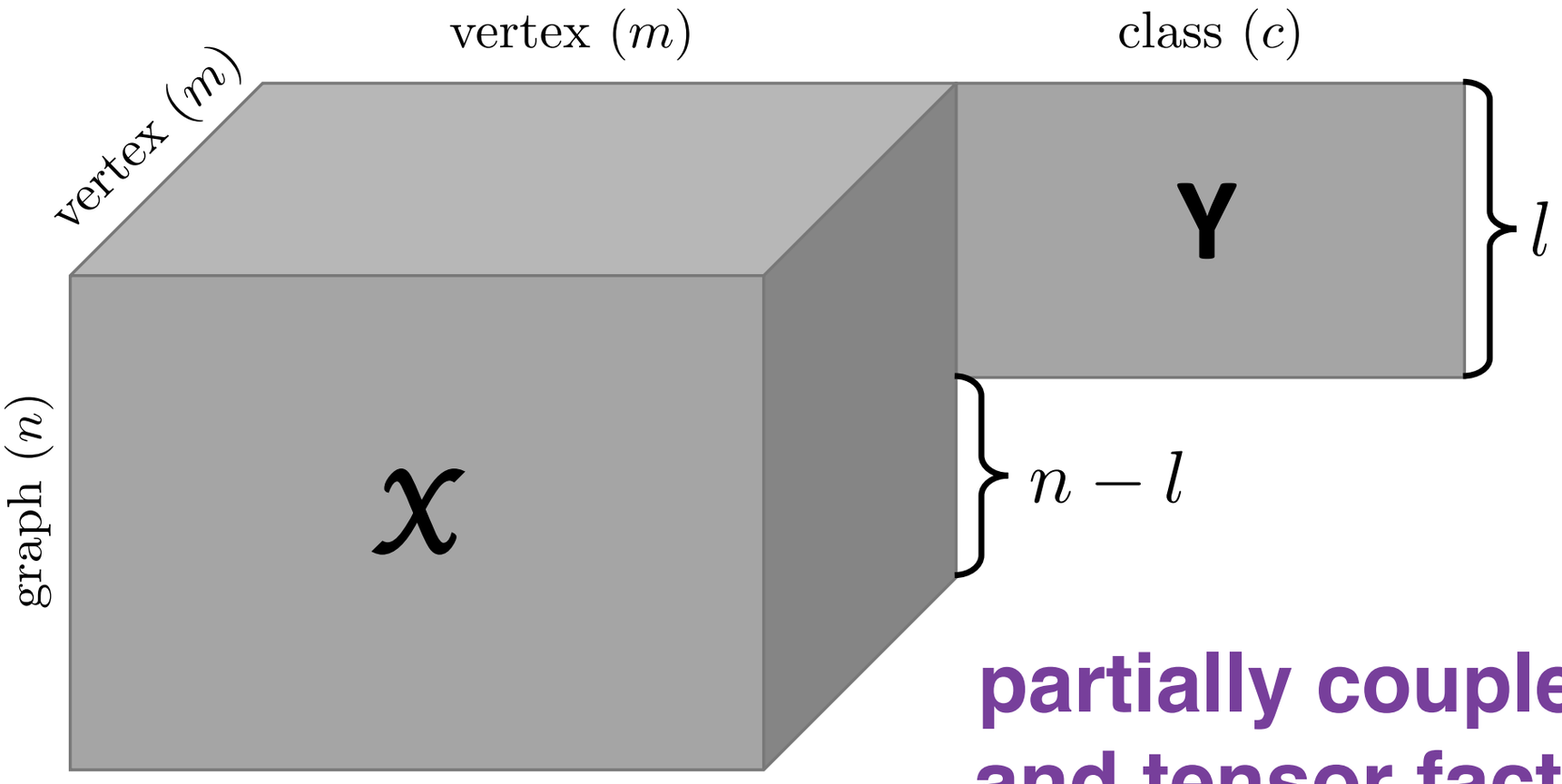
Problems & Solutions

- (P2) How can we directly fully utilize the temporal information in our model?



Problems & Solutions

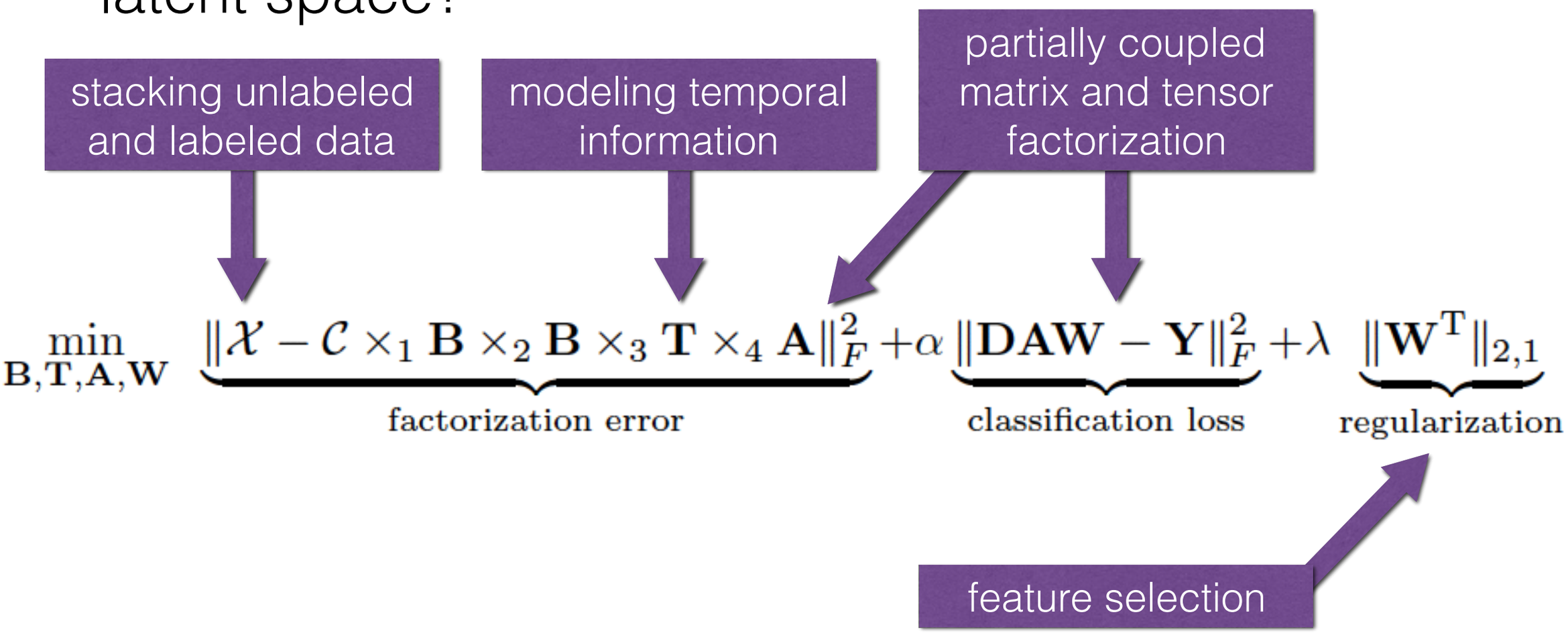
- (P3) How can we effectively fuse these two procedures together?



partially coupled matrix and tensor factorization

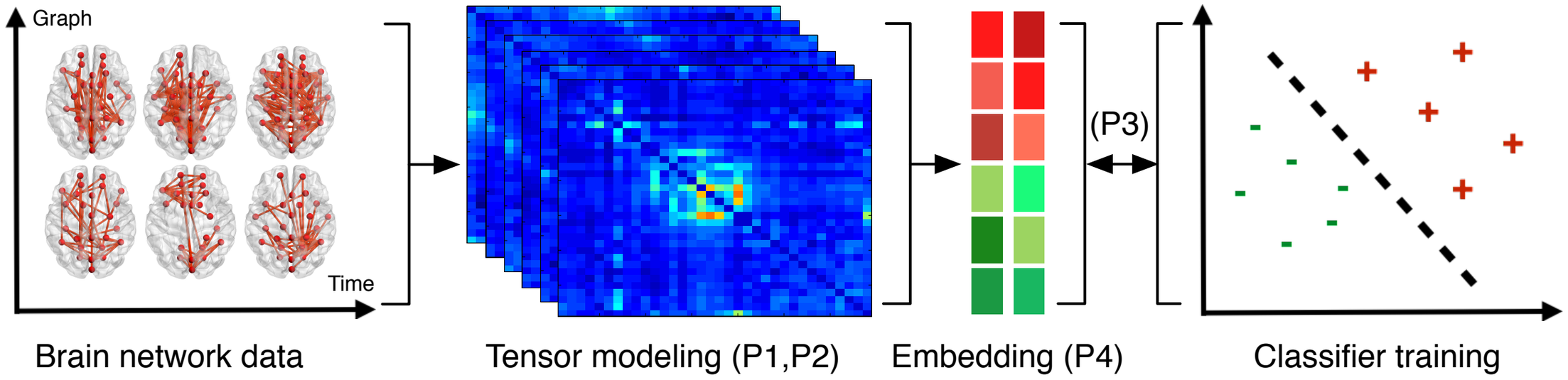
Problems & Solutions

- (P4) How can we achieve feature selection in the latent space?



Tensor-based Framework

$$\min_{\mathbf{B},\mathbf{T},\mathbf{A},\mathbf{W}} \underbrace{\|\mathcal{X} - \mathcal{C} \times_1 \mathbf{B} \times_2 \mathbf{B} \times_3 \mathbf{T} \times_4 \mathbf{A}\|_F^2}_{\text{factorization error}} + \alpha \underbrace{\|\mathbf{DAW} - \mathbf{Y}\|_F^2}_{\text{classification loss}} + \lambda \underbrace{\|\mathbf{W}^{\mathrm{T}}\|_{2,1}}_{\text{regularization}}$$
$$\text{s.t.} \quad \underbrace{\mathbf{A}^{\mathrm{T}}\mathbf{A} = \mathbf{I}}_{\text{orthogonality}} \tag{2}$$



- semiBAT: the proposed semi-supervised brain network analysis approach based on constrained tensor factorization.

Optimization: ADMM

Algorithm 1 semiBAT

Input: $\mathcal{X}, \mathbf{Y}, \alpha, \lambda$

Output: $\mathbf{B}, \mathbf{T}, \mathbf{A}, \mathbf{W}$

Set $\upsilon_{max} = \phi_{max} = \psi_{max} = 10^6, \rho = 1.15$
Initialize $\mathbf{B}, \mathbf{T}, \mathbf{A}, \mathbf{W} \sim \mathcal{U}(0,1), \Upsilon = \Phi = \Psi = \mathbf{0}, \upsilon = \phi = \psi = 10^{-6}$
repeat
    Update $\mathbf{B}$ and $\mathbf{P}$ by Eq. (5) and Eq. (7)
    Update $\mathbf{T}$ by Eq. (9)
    Update $\mathbf{A}$ and $\mathbf{Q}$ by Eq. (12) and Eq. (13)
    Update $\mathbf{W}$ by Eq. (16)
    Update Υ, Φ and Ψ by Eq. (8) and Eq. (14)
    $\upsilon \leftarrow \min(\rho\upsilon, \upsilon_{max})$, $\phi \leftarrow \min(\rho\phi, \phi_{max})$, $\psi \leftarrow \min(\rho\psi, \psi_{max})$
until convergence

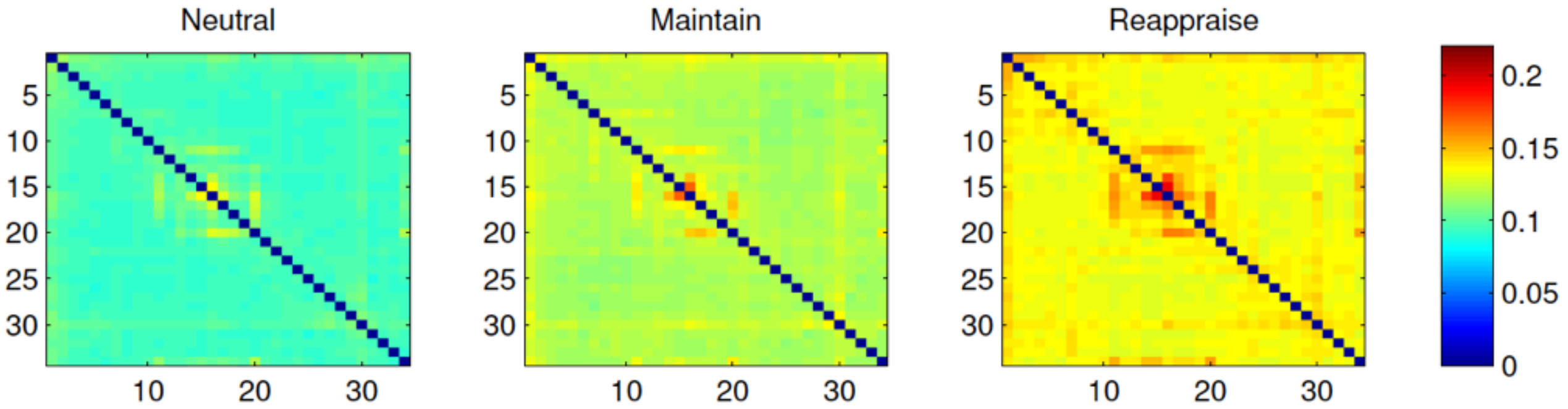
code available at: https://www.cs.uic.edu/~bcao1/code/semibat.zip

Experiments

Training: 22 healthy participants at the University of Illinois at Chicago (UIC)
Test: 11 healthy participants at the University of Michigan (UMich)

Unlabeled data: resting-state (UIC only)
Labeled data: neutral, maintain, reappraise

n = 22 * 4 + 11 * 3 = 121 samples
m = 34 scalp channels
t = 130 time points

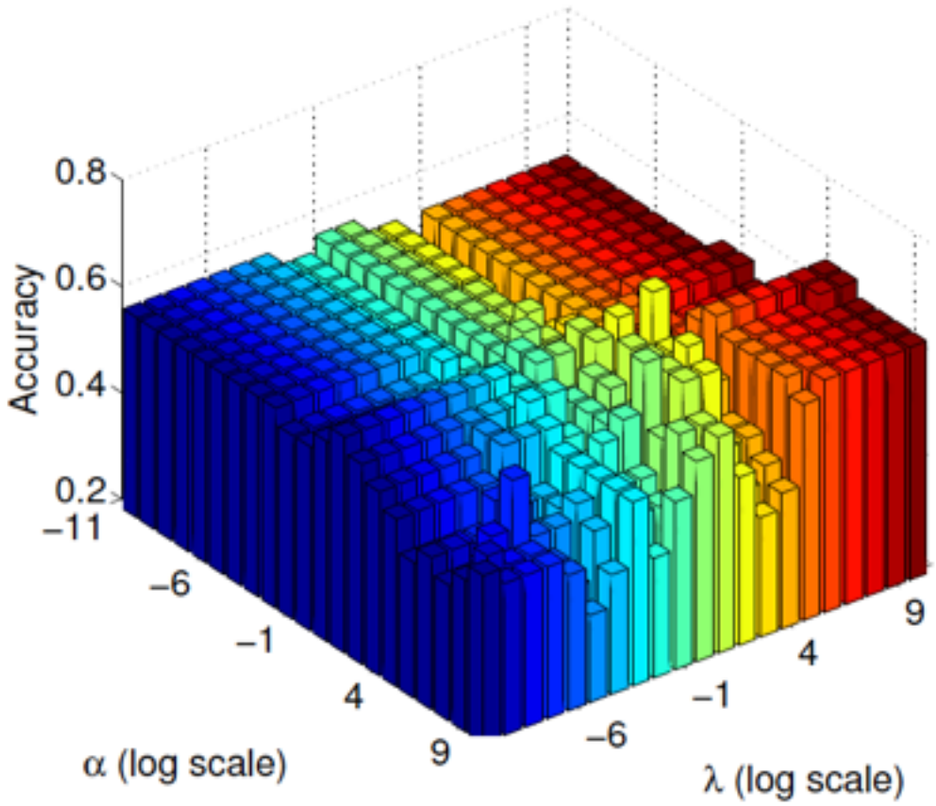


Classification Performance

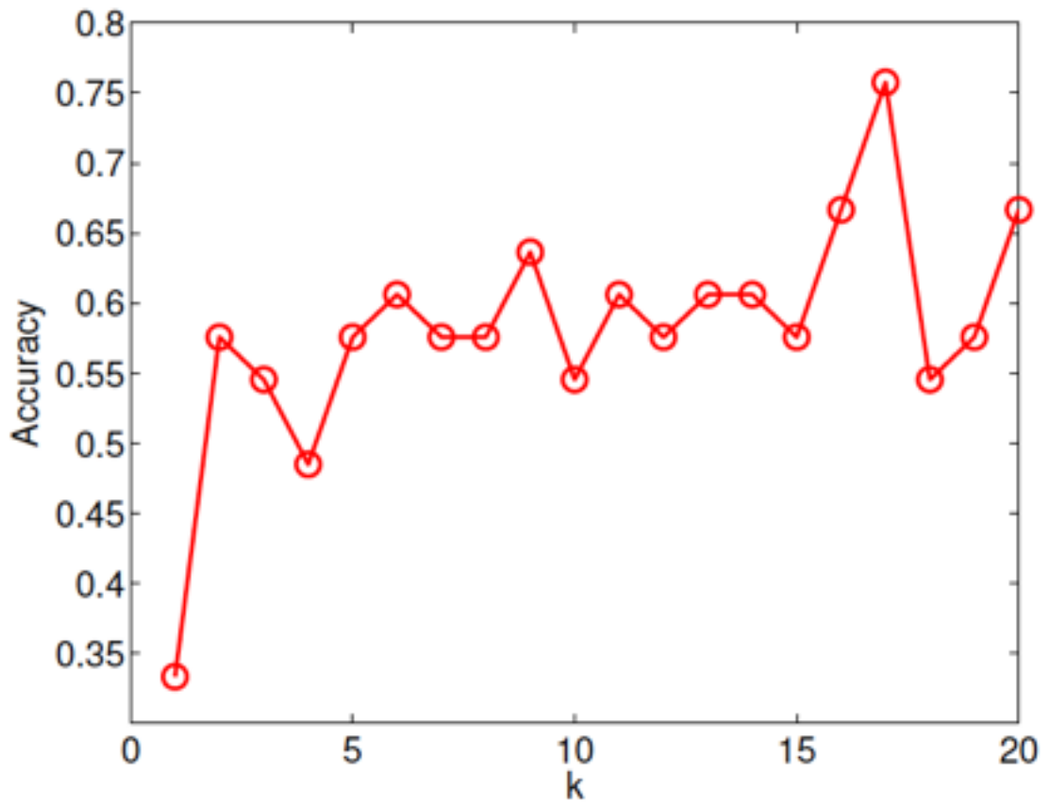
Methods	Evaluation metrics							
	Accuracy	Precision			Recall			F1
		N	*M*	*R*	*N*	*M*	*R*	
semiBAT	**0.758**	0.833	**0.889**	0.667	**0.833**	0.667	**0.833**	**0.765**
BAT-ridge	0.697	**0.909**	0.700	0.600	**0.833**	0.583	0.750	0.706
BAT-supv	0.697	0.714	0.750	**0.700**	**0.833**	**0.750**	0.583	0.706
BAT-unsupv	0.576	0.818	0.600	0.467	0.750	0.500	0.583	0.588
BAT-3d	0.545	0.857	0.538	0.500	0.500	0.583	0.667	0.559
ALS	0.576	0.750	0.636	0.462	0.750	0.583	0.500	0.588
Subgraph	0.515	0.800	0.500	0.444	0.667	0.333	0.667	0.529
CC	0.364	0.286	0.667	0.391	0.167	0.333	0.750	0.382
Edge	0.455	0.462	0.700	0.385	0.500	0.583	0.417	0.471

- BAT-ridge: replacing the L2,1 norm in semiBAT with a regular ridge term.
- BAT-supv: a fully supervised variant of semiBAT without leveraging the unlabeled data.
- BAT-unsupv: an unsupervised variant of semiBAT.
- BAT-3d: applying semiBAT on time-averaged brain networks.
- ALS: tensor factorization using alternating least squares without any constraint.
- Subgraph: a discriminative subgraph selection method.
- CC: extracting local clustering coefficients as features.

Parameter Sensitivity

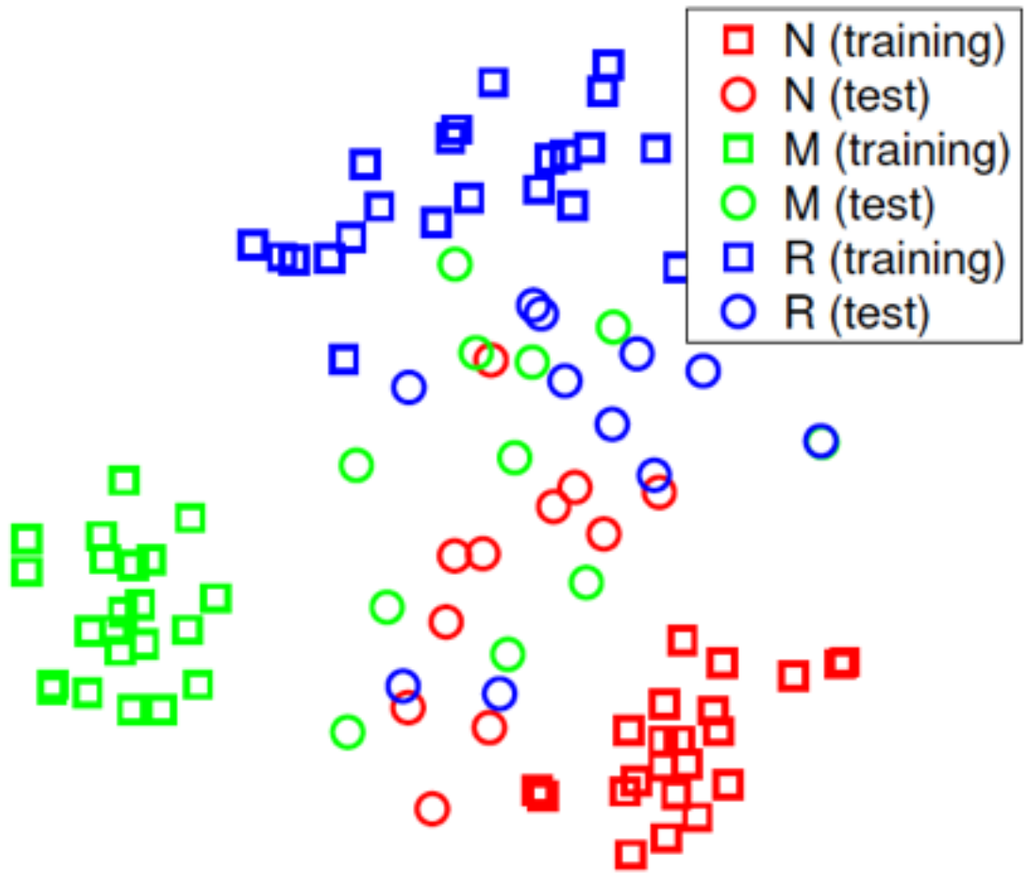


Sensitivity w.r.t. α and λ

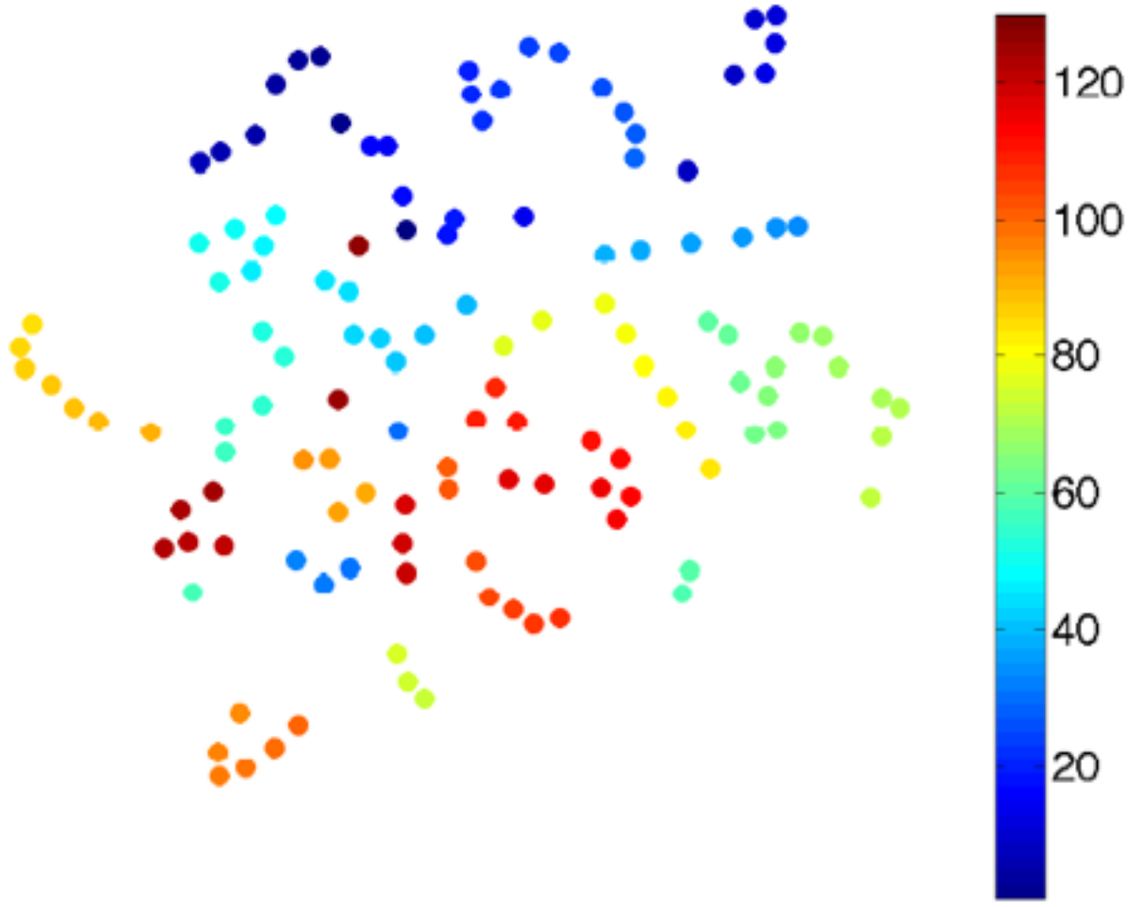


Sensitivity w.r.t. k

Row-wise Factor Analysis

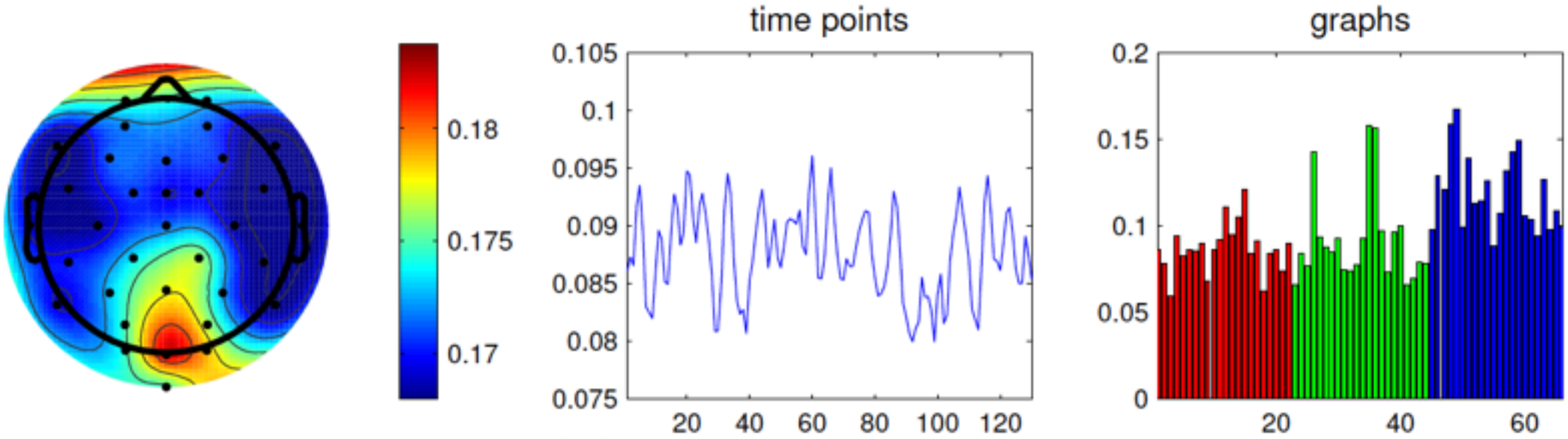


Embedding of brain networks

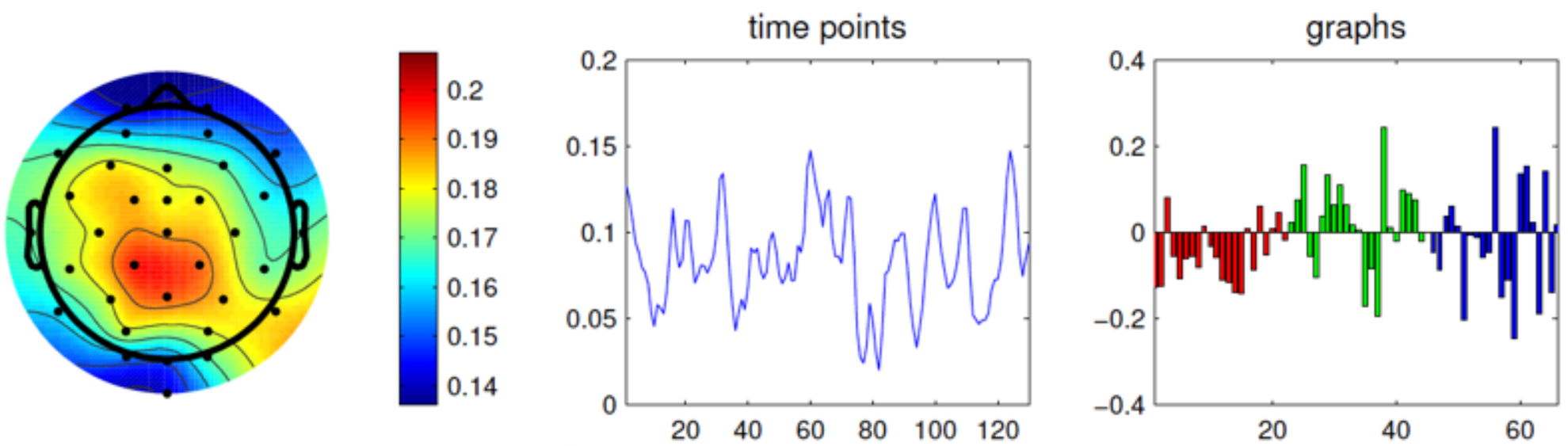


Embedding of time points

Column-wise Factor Analysis



(a) The first factor.



(b) The second factor.

Summary

- Leveraged unlabeled brain networks for task recognition
- Explored the temporal dimension to capture the progress
- Incorporated classifier learning procedure in tensor factorization
- Selected discriminative latent factors for different tasks
- Facilitated better understanding of brain mechanism under emotion regulation