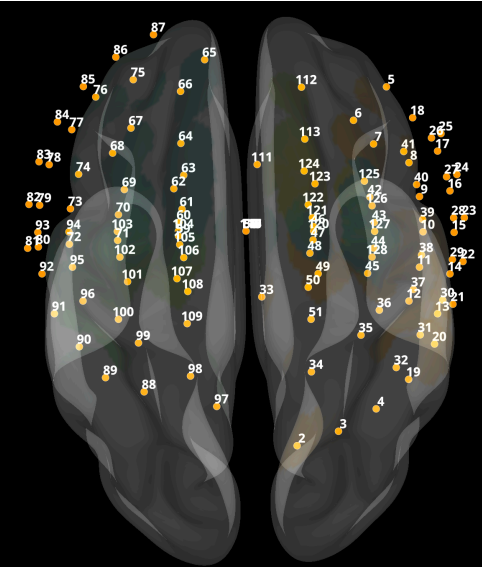


### EEG: Measuring our Working Memory

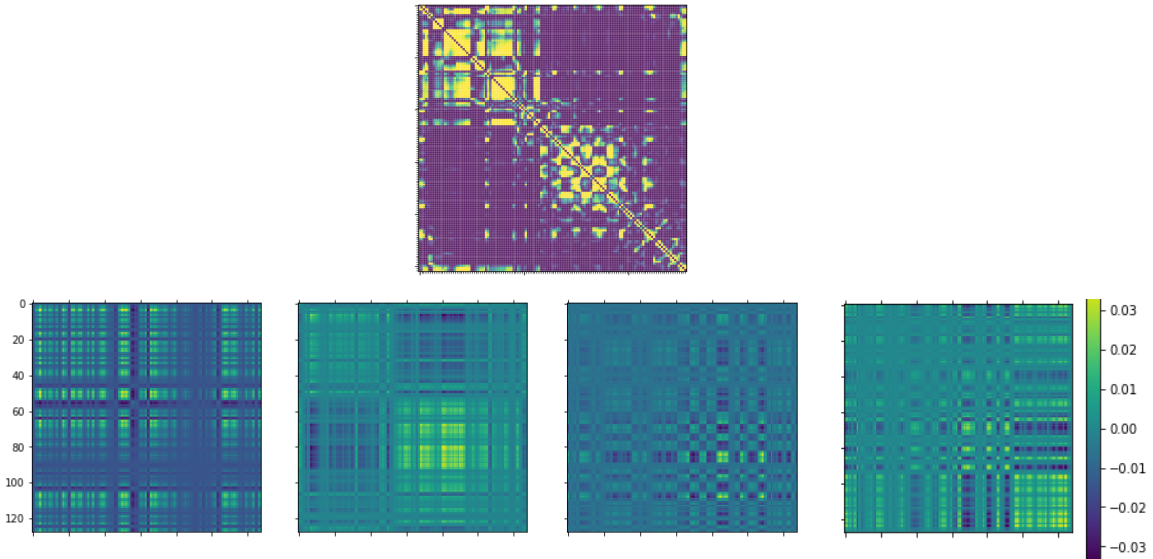
#### Dataset

- The data was collected in a study of human brain functional connectivities in working memory.
- 20 healthy subjects were asked to do the Sternberg verbal working memory task with three levels of memory load (load 2, 4 and 6). The subjects were wearing EEG head caps with 128 channels of electrodes.



#### Motivation

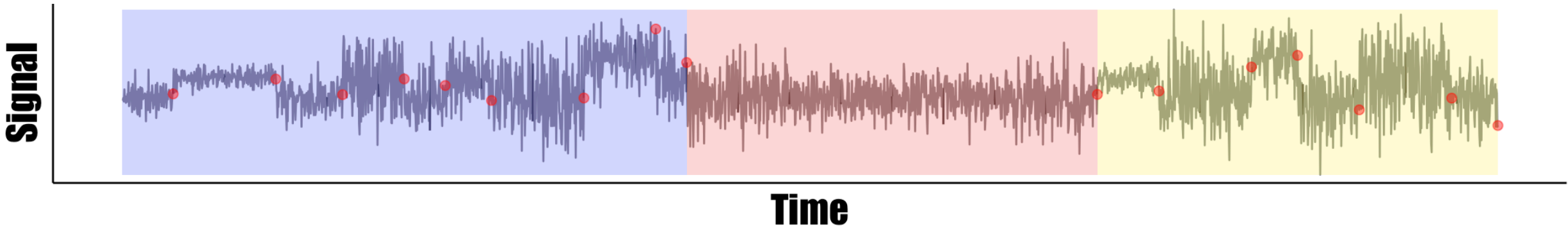
- We extract the correlation between each pair of the channels. We study the adjacency matrices of measurement over time period.
- The brain network is large. However, the brain connectivity displays coarse-grain structures that may relate to latent low-dimensional estimation.
- During different period of memory, and loads, our brains display different connectivity.



### A Case Study: Change Point Detection

We model the change point detection task as a combination of Hidden Markov Model and clustering problem. Suppose there are  $K$  hidden states, where the center for the state is  $\mu^{(k)}$ .  $A_t$  belongs to state  $z_t$ . Denote the transition probability from  $k$  to  $l$  by  $p_{k,l}$ . The likelihood is therefore

$$L(A_t, z_t, \mu^{(z_t)}) = \prod_{t=1}^T p_{z_{t-1}, z_t} \exp\{-\|A_t - \mu^{(z_t)}\|\},$$



#### Period

Encoding  
Retention  
Retrieval

### Treed-SVD: Partition the Brian Network

#### Framework:

- For a given adjacency matrix  $A$ , we want to find out the Treed-SVD decomposition as

$$A = P\Lambda P^T,$$

where  $P$  is an orthonormal matrix and every column of  $P$  displays a level partition.

- The structure is generated level-by-level:

1. Compute the eigenvector of  $A$  corresponding to the largest eigenvalue, and partition by the sign as  $\mathcal{T}_{l,s}$ .
2. Solve the quadratic programming

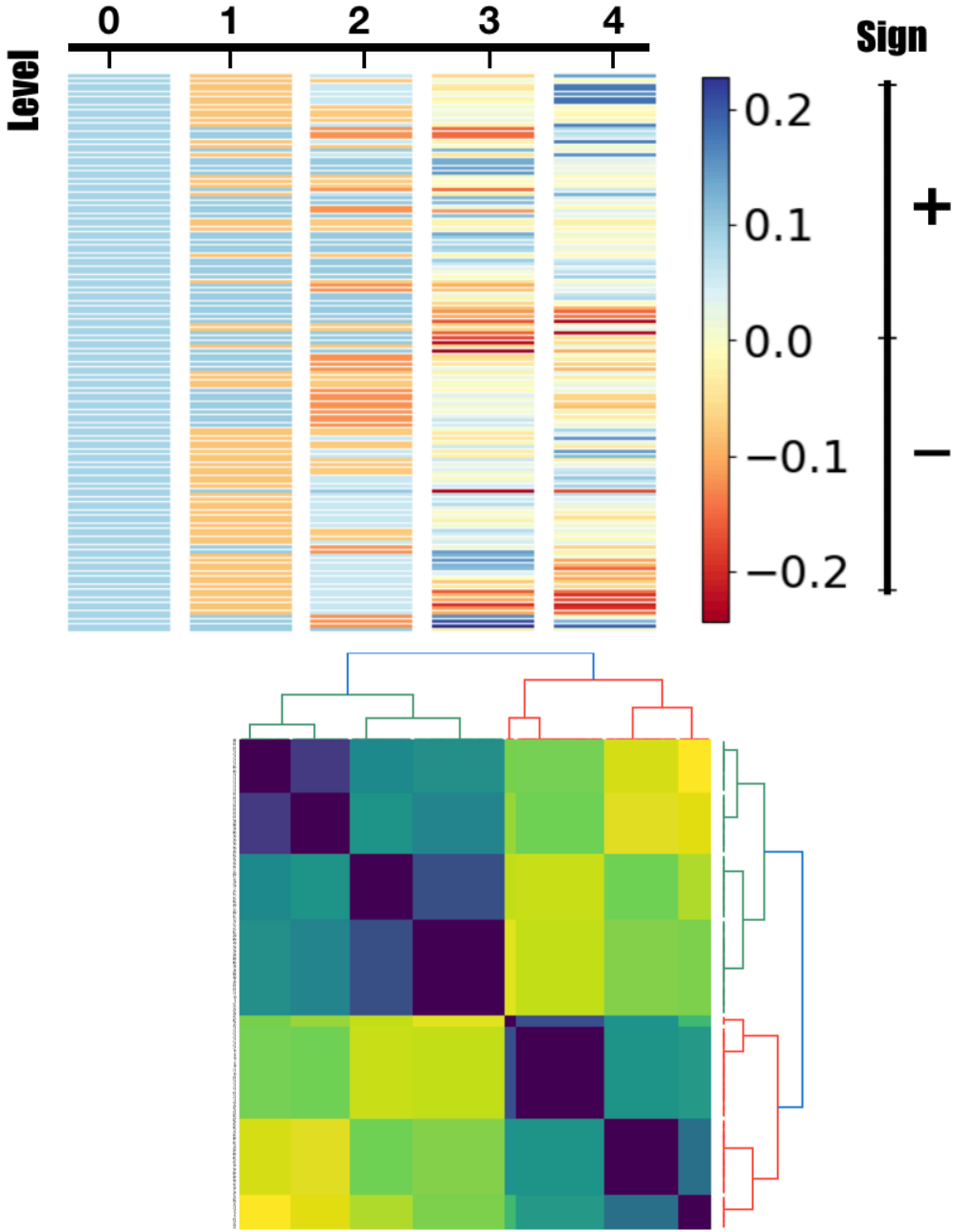
$$\arg \min_{\lambda_k, p_k} \|R_{k-1} - \lambda_k p_k p_k^T\|_F$$

$$\text{subject to } (p_1, p_2, \dots, p_k) \sim \{\mathcal{T}_{l,s}\}_{l=1, \dots, s}$$

and set

$$\lambda_k = \text{tr}(p_k^T R_{k-1} p_k).$$

3. Compute the residual matrix as  $R_k = R_{k-1} - \lambda_k p_k p_k^T$ .



### The Hidden Markov Clustering

1. Conditioned on  $\{z_t\}_{t_r}$ , update  $\{\mu^{(k)}\}_k$  using Treed-SVD algorithm.
2. Conditioned on  $\{\mu^{(k)}\}_k$ , update the latent assignment one-at-a-time, from the categorical distribution with

$$pr(z_t = k \mid z_{t-1}, z_{t+1}) = \frac{p_{z_{t-1}, k} p_{k, z_{t+1}} \exp\{-\|A_t - \mu^{(k)}\|\}}{\sum_{l=1}^K p_{z_{t-1}, l} p_{l, z_{t+1}} \exp\{-\|A_t - \mu^{(l)}\|\}}$$

3. Conditioned on  $\{z_t\}_{t_r}$ , update the transition probabilities by

$$(p_{k,1}, \dots, p_{k,K}) \sim \text{Dir}\{\alpha + \sum_{t=1}^T \mathbf{1}(z_{t-1} = k, z_t = 1), \dots, \alpha + \sum_{t=1}^T \mathbf{1}(z_{t-1} = k, z_t = K)\}$$

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