Classification of Brain Activity using Synolitic Networks

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Introduction

Full-scale analysis of brain activity is a daunting task. Methods of network representation of brain data (e.g., fMRI) with subsequent statistical analysis have been proved to be effective in such tasks.

We propose a method of representing fMRI data in the form of graphs that would reflect meaningful information about relationships between brain regions. Effectiveness of the method has been verified by classification of brain activity.

Method of representing fMRI data as a network

Ω is a set of fMRIs, and Σ is a set of brain activity modes ($\sigma \in \Sigma$ is 1 or 2).

1. **Convert $\omega \in \Omega$ into 4D array a.** So $a_{xyzt} \in \mathbb{R}_+$, and a_{xyz} is a vector.

Each vertex v_i in the graph g reflects a voxel i in the fMRI data, each edge e_{ij} between the vertices v_i, v_j and edge weight w_{ij} reflect the relationships between voxels i, j.

2. **Calculate vertex values $\{r_i\}_i$.** To do that use function T (e.g., median). So $r_i = T(a_{xyz})$.
3. **Make edges $\{e_{ij}\}_{ij}$ between adjacent voxels.** Due to the huge number of voxels, we propose to construct a lattice graph.
4. **Calculate edge weights $\{w_{ij}\}_{ij}$ as follows:**

$$w_{ij} = P(\sigma = 2|r_i, r_j) - P(\sigma = 1|r_i, r_j).$$

If $w_{ij} < 0$, then edge e_{ij} carries information that the most probable brain mode is 1. If $w_{ij} > 0$, then this edge carries information that the most likely mode is 2.

We used SVMs $Cl_{ij} : \{\sigma|(r_i, r_j)\} \to [0, 1]$ to compute $\{w_{ij}\}_{ij}$.

5. **Remove edges $\{e_{ij} : r_i < r | r_j < r | |w_{ij}| < w\}_{ij}$ with specific parameters r, w.** They don't provide useful information.

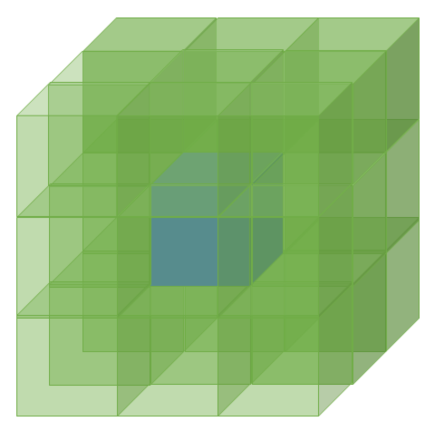

Figure 1. Adjacent voxels to the central one.

Classification based on graph properties

1. **Compute properties $\{f_u\}_u = \{F_u(g)\}_u$ of graph g.** We used mean of edge weights, variance of edge weights and different quantiles.
2. **Perform classification of fMRI data using classifier Cl.** We used SVM.

Data for verification

We tested the method on data from the study (Horikawa T., Kamitani Y. 2019) in which fMRI data were recorded while subjects viewed images of objects or imagined objects with their eyes closed.

	seen		imagined		
	training	test	training	test	
sub-01	17	7	14	6	44
sub-02	17	7	14	6	44
sub-03	17	7	14	6	44
sub-04	17	7	14	6	44
sub-05	16	8	14	6	44
	84	36	70	30	220
	120		100		

Table 1. Dividing the sample into training and test parts.

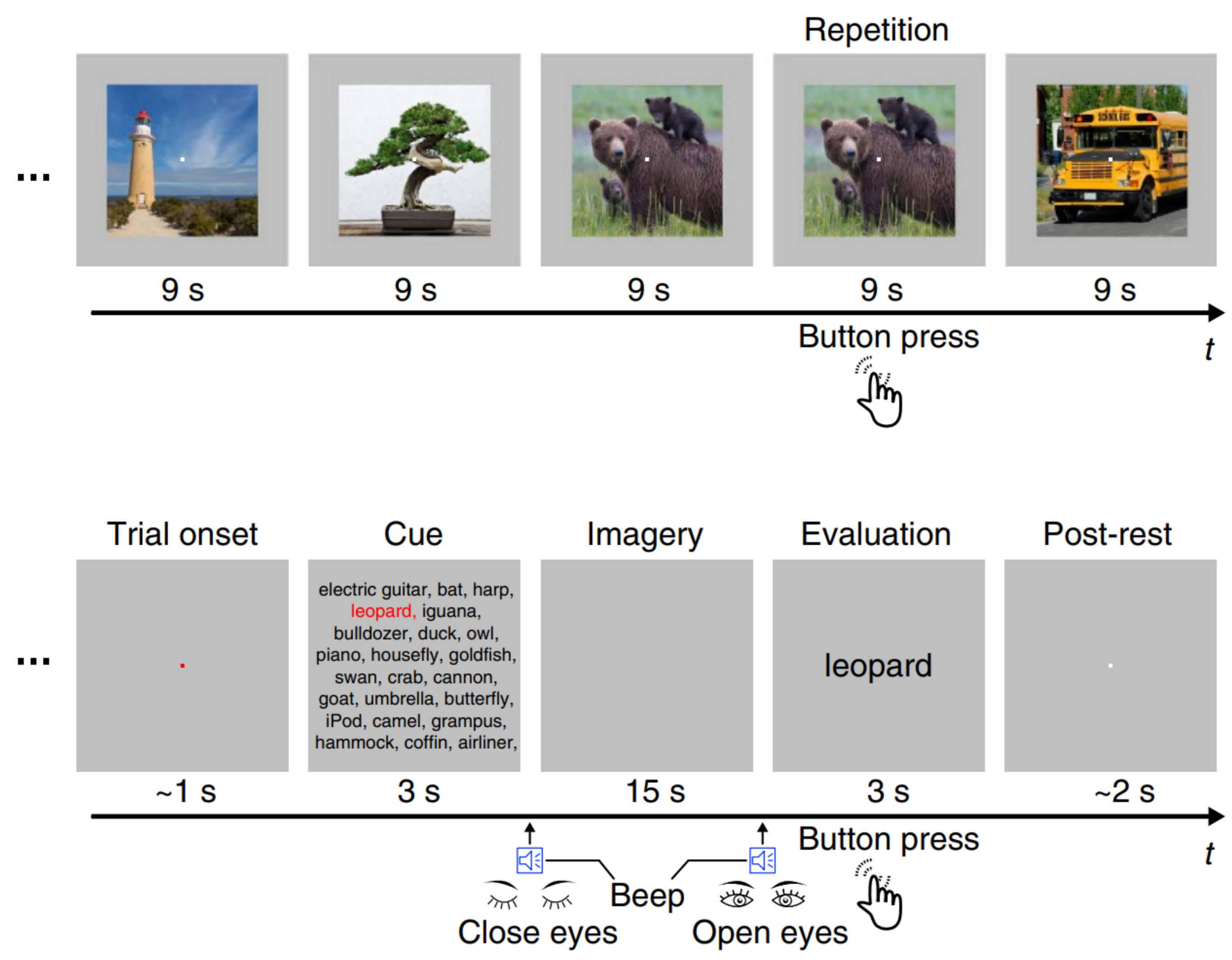

Figure 2. Two modes of brain activity.

Classification accuracy

The accuracy of the method for different T did not fall below 90%. The best classification result was obtained when T was chosen as the median of voxel ($r = 1$, $w = 0.2$). It was 98.5%.

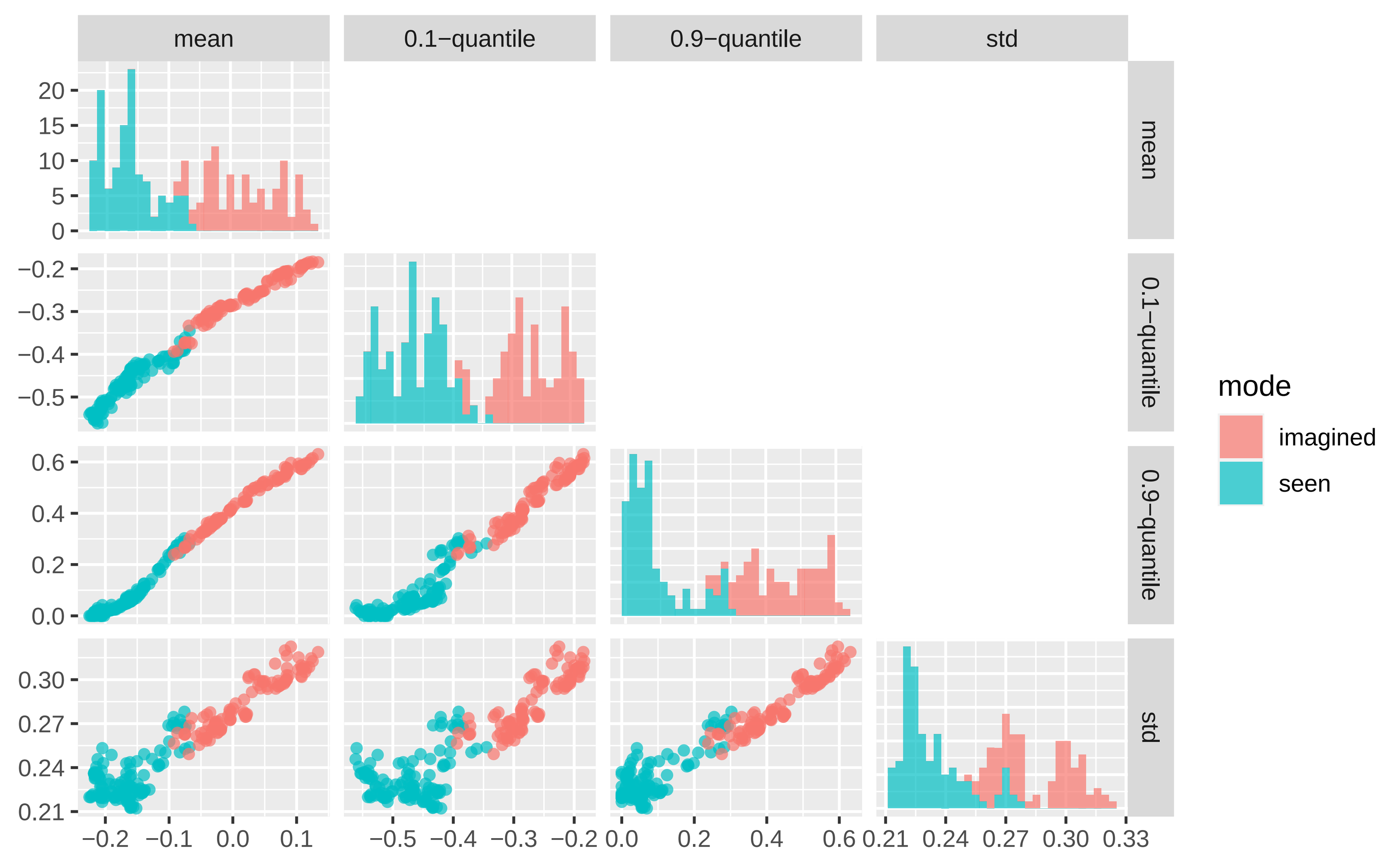

Figure 3. Distributions of graph properties when T is the median ($r = 1$, $w = 0$).

	seen	imagined
seen	36	0
imagined	1	29

Table 2. The classification matrix when T is the median ($r = 1$, $w = 0.2$).

Conclusion

We proposed the method of representation of fMRI data in a form of synolitic networks. Classification of graph properties showed high accuracy, from which it can be concluded about the effectiveness of the method.

References

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