IN SEARCH FOR BRAIN FUNCTIONAL CONNECTIVITY

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Problem Statement

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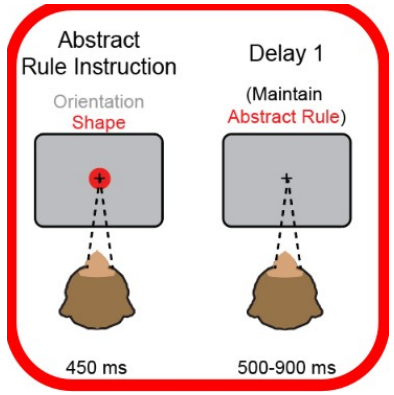
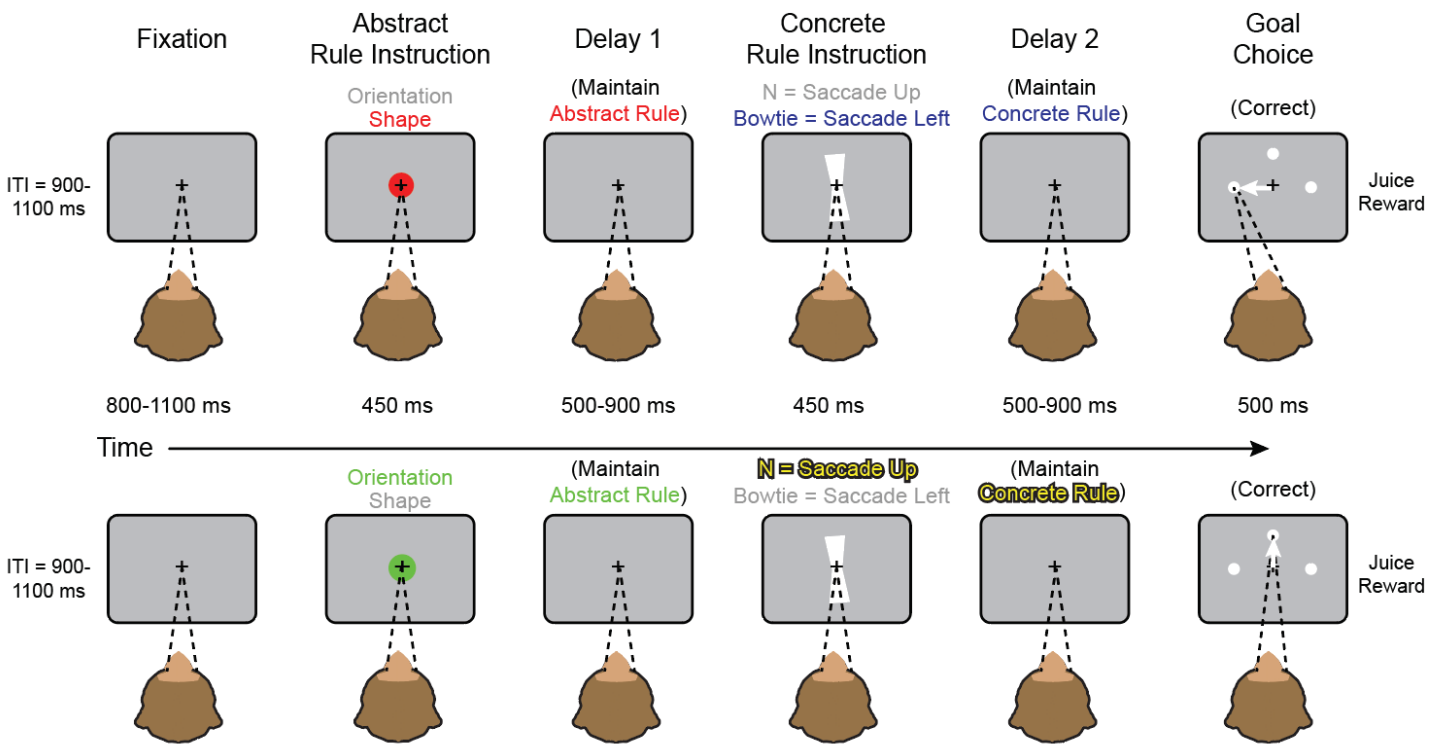
- Signal processing based on structured data including:
  - Biology networks
  - Social networks
  - Brain networks
- Searching for the functional connectivity in the brain
  - Do different cues effect neurons activity in different areas?
  - Data are sampled from a set of electrodes placed in cortex and thalamus of the brain
  - Inference from multivariate time series (low field potential, LFP)



(Jessica M. Phillips et. al.)

Monkey Experiments



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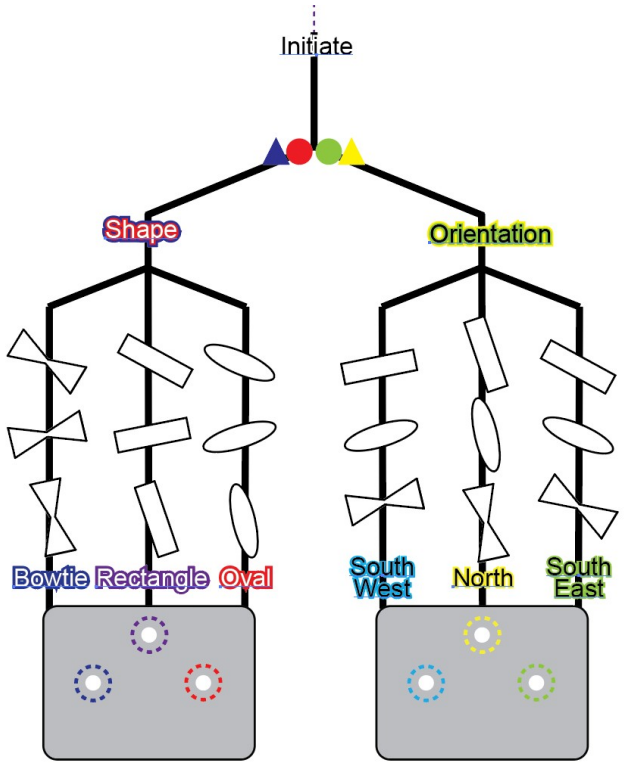

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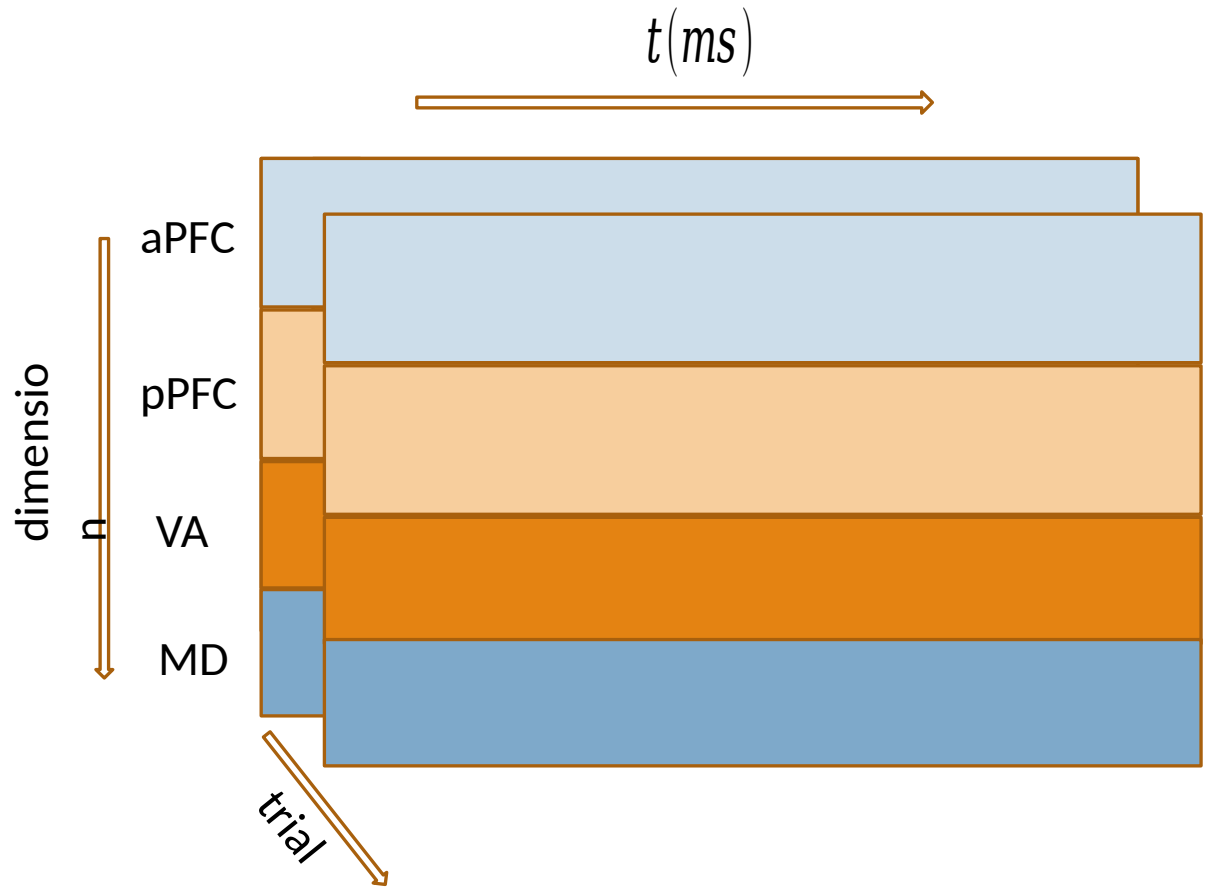
The Dataset

- LFP signal
- Cortex
  - aPFC: channel number
  - pPFC: channel number
- Thalamus
  - MD: channel number
  - VA: channel number



Graph Basics

- A weighted graph:
  - A set of vertices:
  - A set of edges:
  - A weighted adjacency matrix:
- Degree matrix: =
- Graph Laplacian matrix:

Graph Learning Method

- We find Jointly and $\min_{L,y} ||x-y||_2^2 + \alpha\ y^T L y.$
  - is observations, is graph signal
  - $\alpha\ y^T L y$ measure the smoothness of the signal on graph
  - is close to the observation , and at the same time is smooth on the learned graph
  - Learning process: $\min_{L}\ \alpha\ tr(Y^T L Y) + \beta ||L||_F^2,$

    $\text{s.t.}\quad tr(L) = n,$

    $L_{ij} = L_{ji} \leq 0,\ \ i \neq j,$

    $L \cdot \mathbf{1} = \mathbf{0}.$

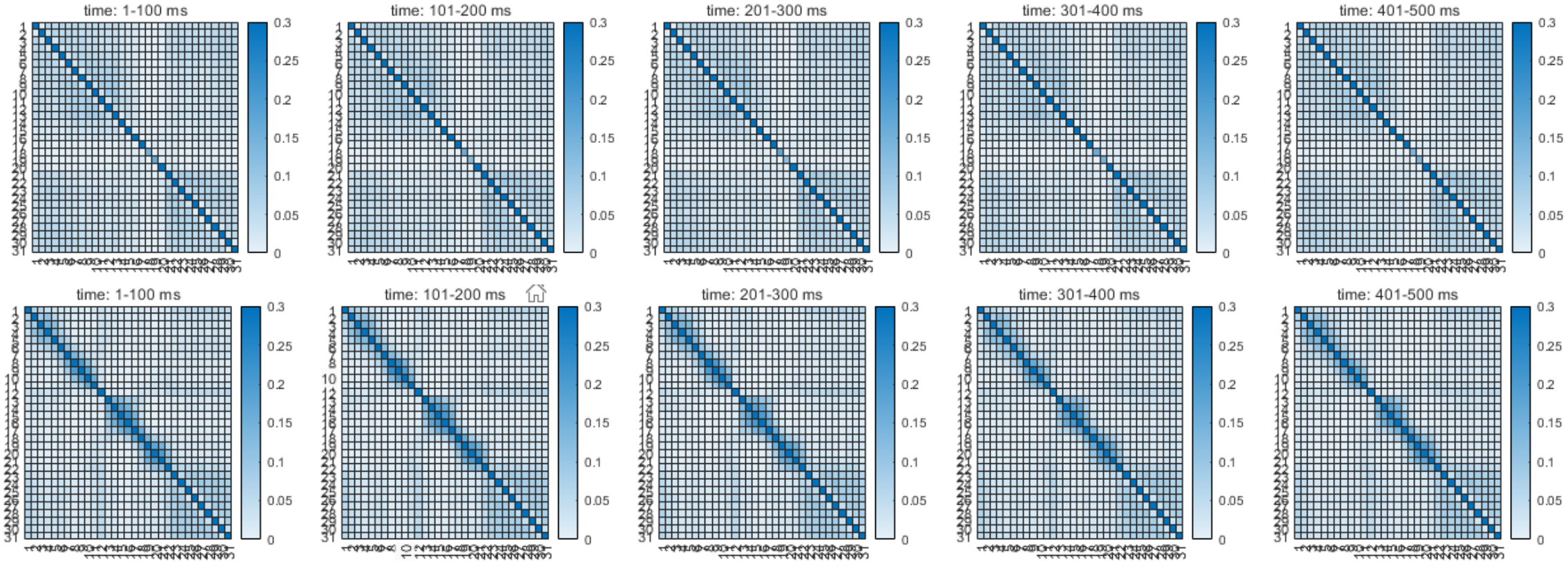
  - Denoising process: $Y = (I_n + \alpha L)^{-1} X.$

LFP Result

- Bipolar data
  -
  - Remove common noise in nearby channels
- We estimate the trial by trial and compute average of it

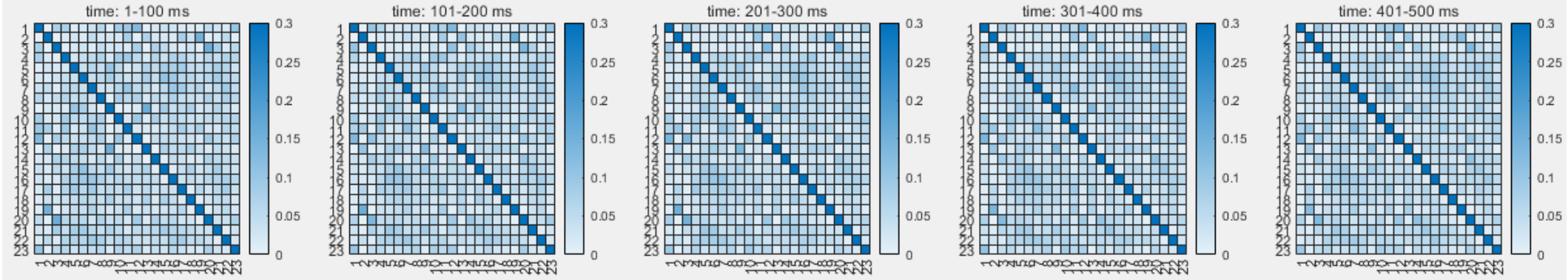
Result from Cortex in Delay 1 Epoch

- aPFC & pPFC:



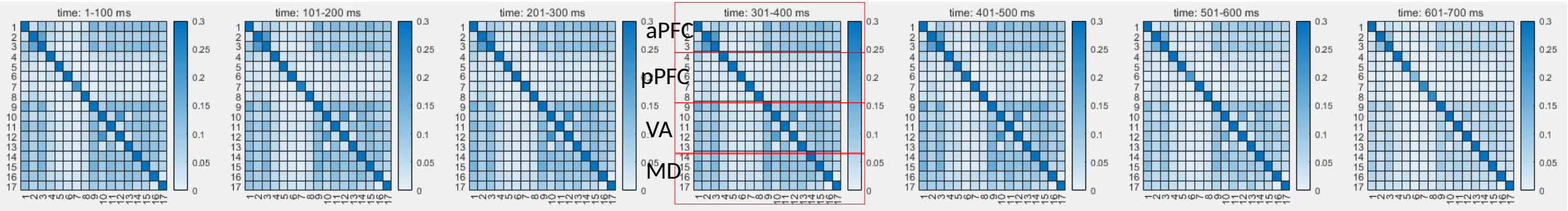
Result from Thalamus in Delay 1 Epoch

- VA & MD
- In the Thalamus, neurons don't talk to each other

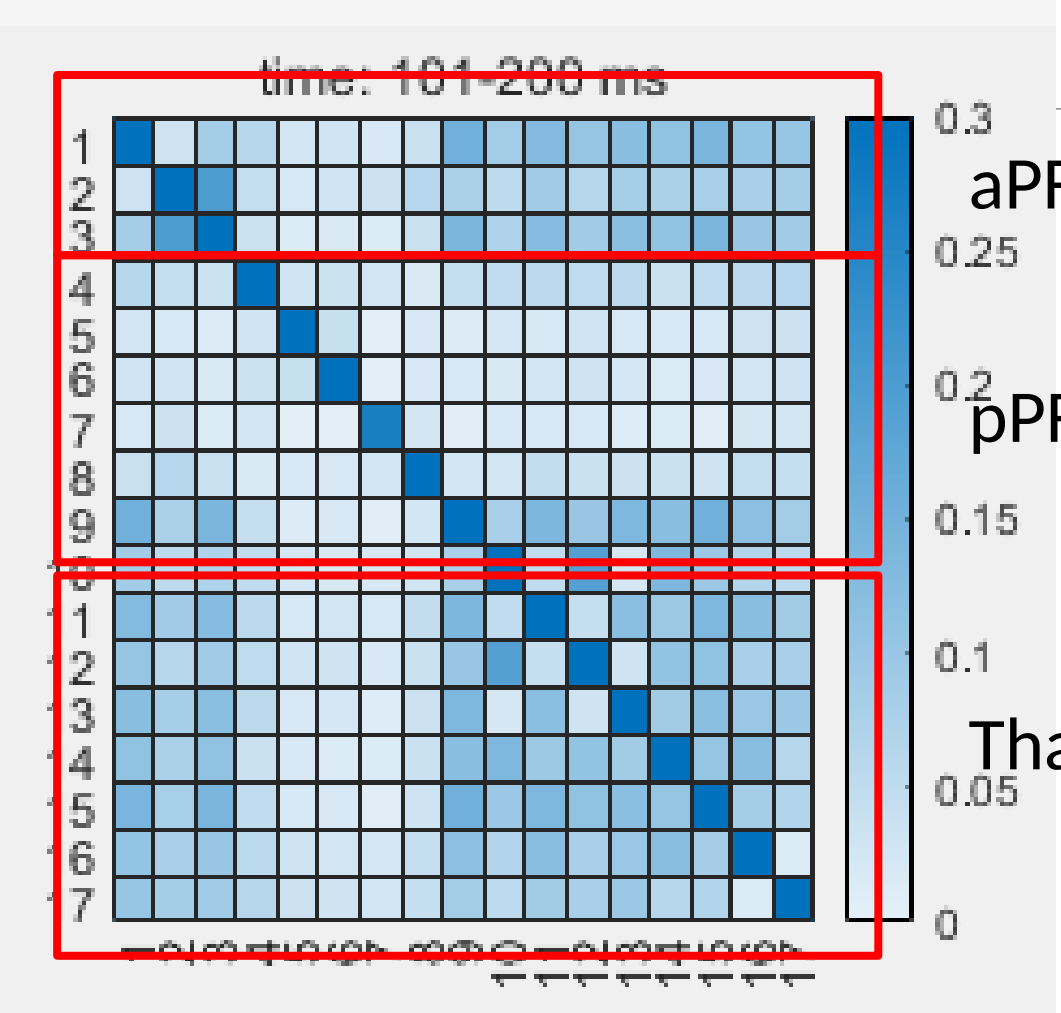


Results from All Areas in Delay 1 Epoch

- Aggregated Data, calculate mean value of nearby channels
  - Node 1 - 3: aPFC
  - Node 4 – 9: pPFC
  - Node 10-13: VA
  - Node 14-17: MD



Hypothesis: thalamus ‘talks to’ aPFC after abstract cue showed



- Aggregated Data, calculate mean value of nearby channels
  - Node 1 - 3: aPFC
  - Node 4 – 9: pPFC
  - Node 10-13: VA
  - Node 14-17: MD

Current/future Work

- We are working on the development of a Bayesian graph model based on the Laplacian matrix
- We are also working on method based on adjacency matrices, where the graphs have directed edges.
- Future work will include the method presented by Gonzalo

Reference

[1] X. Dong, D. Thanou, P. Frossard and P. Vandergheynst, "Learning Laplacian Matrix in Smooth Graph Signal Representations," in *IEEE Transactions on Signal Processing*, vol. 64, no. 23, pp. 6160-6173, Dec.1, 2016, doi: 10.1109/TSP.2016.2602809.

[2] J. Mei and J. M. F. Moura, "Signal Processing on Graphs: Causal Modeling of Unstructured Data," in IEEE Transactions on Signal Processing, vol. 65, no. 8, pp. 2077-2092, 15 April15, 2017, doi: 10.1109/TSP.2016.2634543.