Population coupling in the mouse visual cortex

A confirmation study using an open dataset

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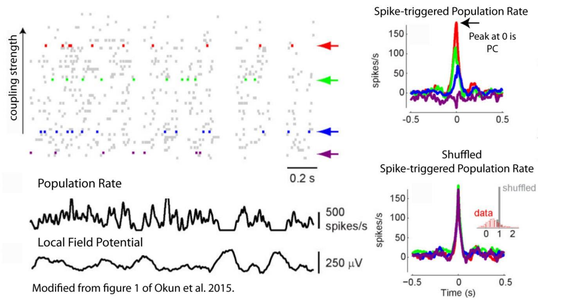
COSYNE **2017**

Population Coupling (PC)



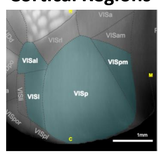
Modified from figure 1 of Okun et al. 2015.

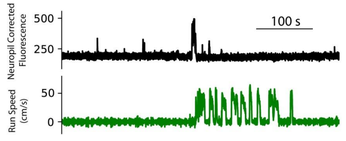
Population coupling (PC) measures a neuron's coordination with the local population activity, with some neurons weakly correlated ('*soloists*') and some neurons strongly correlated ('*choristers*'), and was found to be invariant to experimental conditions (Okun et al., 2015).

We used a recently released open dataset (**http://observatory.brain-map.org/**) to replicate Okun et al.'s findings using calcium recordings of targeted excitatory cell types from the mouse visual cortex.

Data: Allen Institute 'Brain Observatory' of 2P Ca^{2+}

Cortical Regions

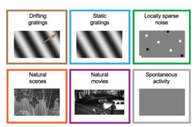




Cell Types and Layers

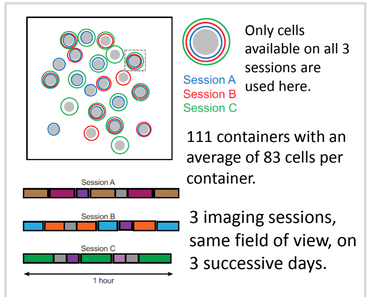
6 cre-GCaMP6f lines to target excitatory cell types in L2-5

Visual Stimuli



Response properties (tuning, etc) calculated for cells.

Experiment container = Recordings from same cells, across three different days



Only cells available on all 3 sessions are used here.

111 containers with an average of 83 cells per container.

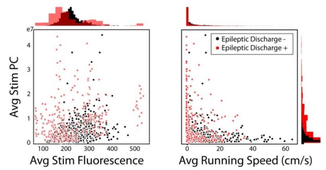
3 imaging sessions, same field of view, on 3 successive days.

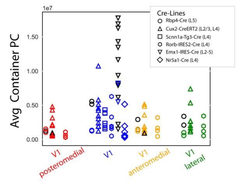
Images from brain-map.org

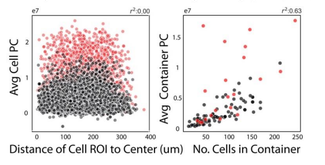
What factors influence PC?

- PC showed a small positive correlation with the *average fluorescence* across all cells.
- *Epileptic discharges* increased the PC, when averaged across all cells or all stimuli.
- *Running speed* showed a small negative correlation with average PC across all cells

We calculated PC for each cell and for each stimulus. To understand the experimental factors that influence PC, we averaged PC over all cells (rows), stims (columns), or all cells and stims within a container. Black marks indicate non-specific GCaMP6f expression or epileptic discharges within a container.

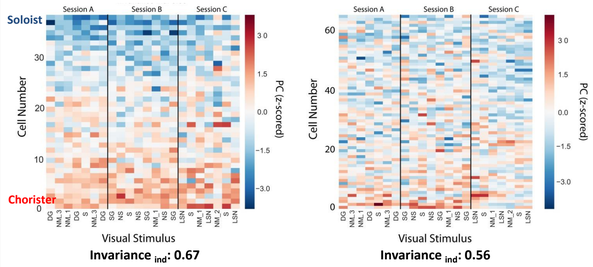




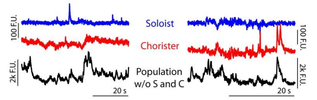


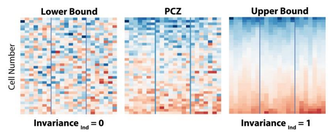
Is relative population coupling (PCZ) invariant to visual stimulus?

We produced a PC matrix for each container, and z-scored the values to ease comparison within and between containers. Rows are sorted by average PCZ across all stimuli.



We found 'soloists', cells with low PC whose activity remained poorly correlated with the population, across different stimuli and recording days. We also found 'choristers', cells with high PC that closely reflected the population activity. This suggests PC is invariant to visual stimuli.



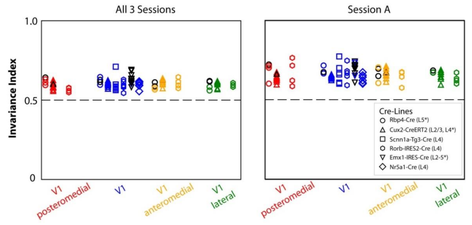


$$Invariance_{ind} = \frac{||PCZ - LB||}{||PCZ - LB|| + ||PCZ - UB||}$$

We quantified the invariance of each container using the relative distance of the PCZ matrix to its lower and upper bound.

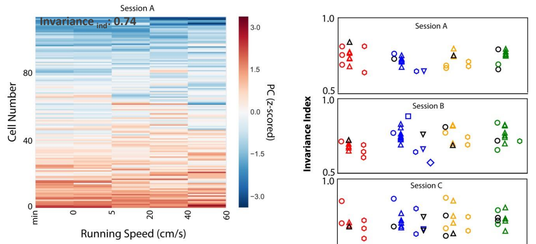
The lower bound matrix was produced by randomly shuffling the cells in each column. The upper bound matrix was produced by sorting the cells by PCZ in each column.

PCZ is invariant to visual stimulus



Each dot is the invariance index (PCZ to visual stimulus) for one container (3 imaging sessions on the same set of cells across 3 days). Black dots indicate epileptic discharges or non-specific GCaMP6f expression. Containers with epileptic discharges tend to have higher invariance indices. No major trends appear with visual area or targeted cell-type.

PCZ is invariant to running speed

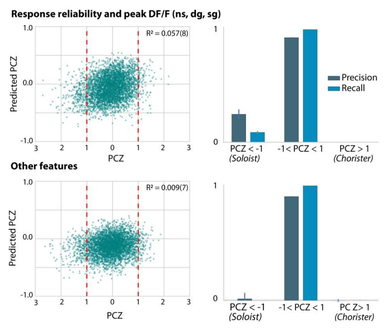


We binned running velocity, and calculated the PC over 'stitched' fluorescence traces in corresponding bins. We only calculated PC and its invariance for sessions in which there was some time spent in each running speed bin.

Each dot is invariance of PC to running for one session. Note that y-scale starts at 0.5.

Relationship between PCZ and visual response properties

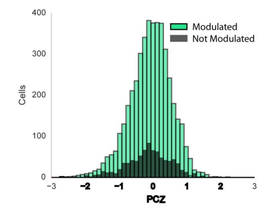
We wanted to understand whether PCZ is correlated with a range off visual response properties, for example a cells' preferred direction. We found little relationship between a cell's PC and its functional properties.

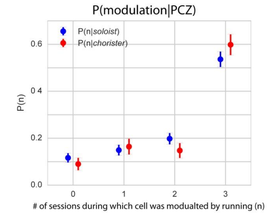


We used various regression methods to predict PCZ from various subsets of the visual response features. The only features that exhibited a significant, albeit weak, predictive power were reliability of response and the peak dF/F. Knn (K=20).

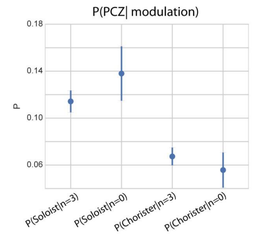
Similarly, classification algorithms failed to predict soloists and choristers by their features, apart from a weak but significant classification of choristers using response reliability and peak dF/F. Linear SVC.

PCZ and modulation by running





Okun et al. predicted that choristers, cells with dense input connectivity from the population, should be more influenced by non-sensory cortical signals such as running. We looked at the relationship between a cell's PCZ and whether or not it was modulated by running (binary index calculated over each session). Although there was a weak positive trend, we did not find a significant relationship between the modulation index and PCZ.



Take-Home

- PC is a simple metric for assessing a cell's synchrony to its population, even when only a specific, sparsely connected, portion of the population is observed.
- The invariance of PC to experimental conditions supports the idea that it reflects the underlying (input) wiring of a cell to its population.
- There is no relationship between a cell's relative PC and its response properties, suggesting that these properties are not overtly affected by input connectivity for excitatory cells in the mouse visual cortex.
- Our results wholly confirm Okun et al.'s findings and predictions, except that we did not observe higher PC values for cells that were modulated by running. Further work will determine if this is a difference in methods, cell types, or results.

Sources and Citations

Okun et al. Nature 521: 511-515, 2015.
Observatory data available at: brain-map.org
Some methods figures from Saskia DeVries slides.
Code: github.com/msarvestani/pop_coupling

This work arose from the Summer Workshop on the Dynamic Brain 2016. We are grateful to all course participants, and in particular to Saskia de Vries and Michael Buice , for guidance.