Detecting change points in neural population activity with contrastive metric learning

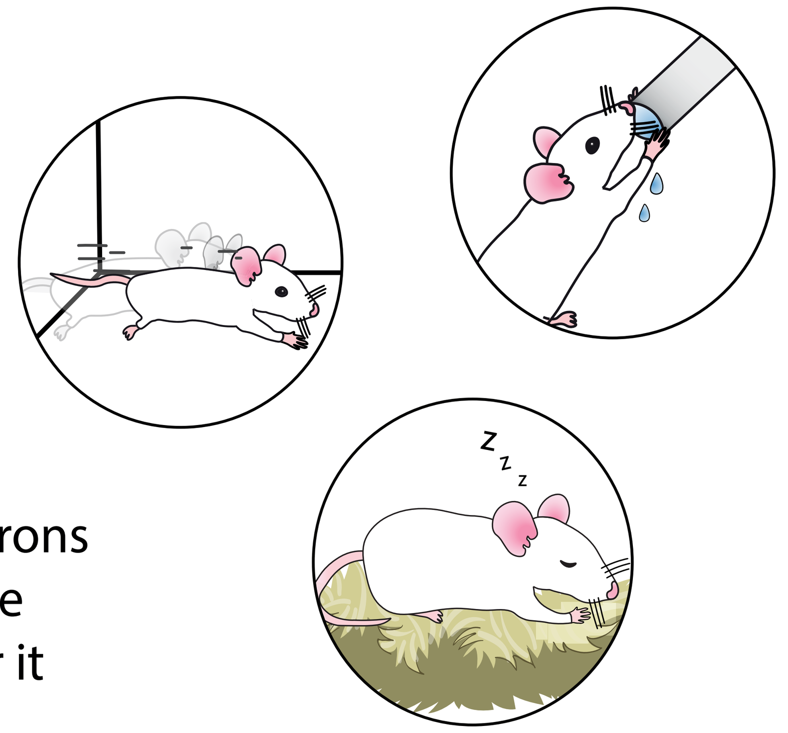
Carolina Urzay[1], Nauman Ahad[1], Mehdi Azabou[1], Aidan Schneider[2], Geethika Atmakuri[1], Keith B. Hengen[2], Eva L. Dyer[1]

[1]Georgia Institute of Technology, [2]Washington University in St. Louis

Motivation

The detection of changes points in neural activity is a challenging task:

- induced by diverse beahvioral switches, which can occur at different rates and impact the population of neurons differently.
- during free behavior, it is hard to identify change points.



Detect a specific type of behavioral switch ⟷ Learn which neurons and signals are responsible for it

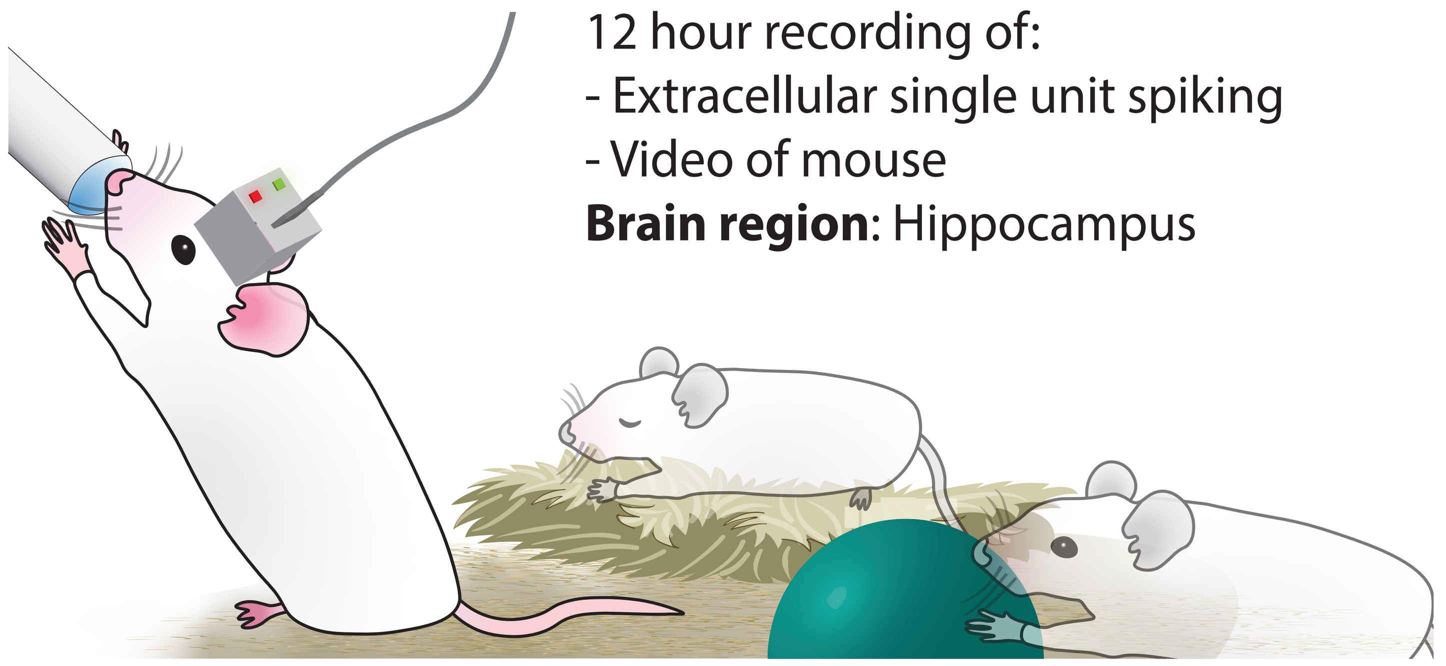
Objective

Goal: improve the detection of specific behavioral switches (change points).
Approach: To detect change points, use the Sinkhorn divergence with a task-relevant metric that is learned from a few labeled change points.

Targeted change point detection tasks:

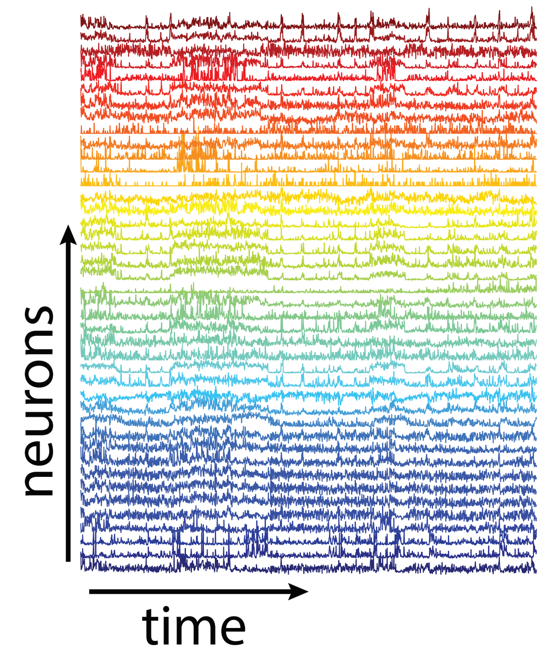
sleep REM/sleep nREM/wake — running/not running

Dataset



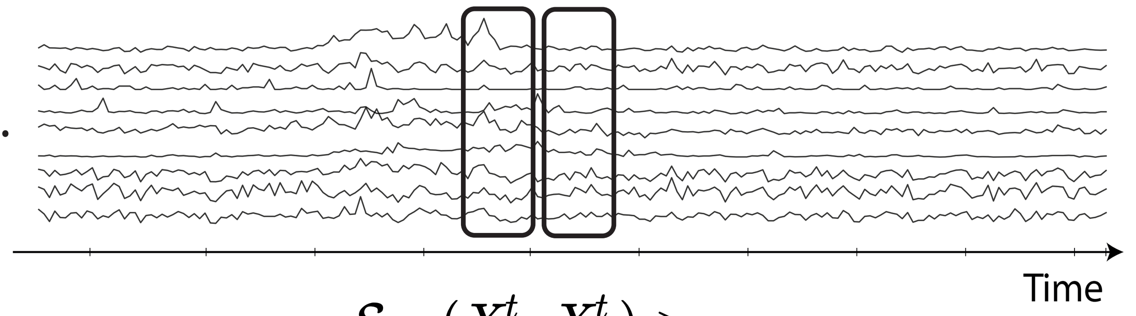
12 hour recording of:
- Extracellular single unit spiking
- Video of mouse

Brain region: Hippocampus



Method

1. Select a window before and a window after a sample of interest.
2. Compute the **Sinkhorn divergence** between the two distributions.
3. A **Change Point** is detected if the divergence is greater than a set threshold.

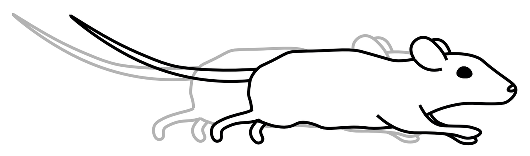


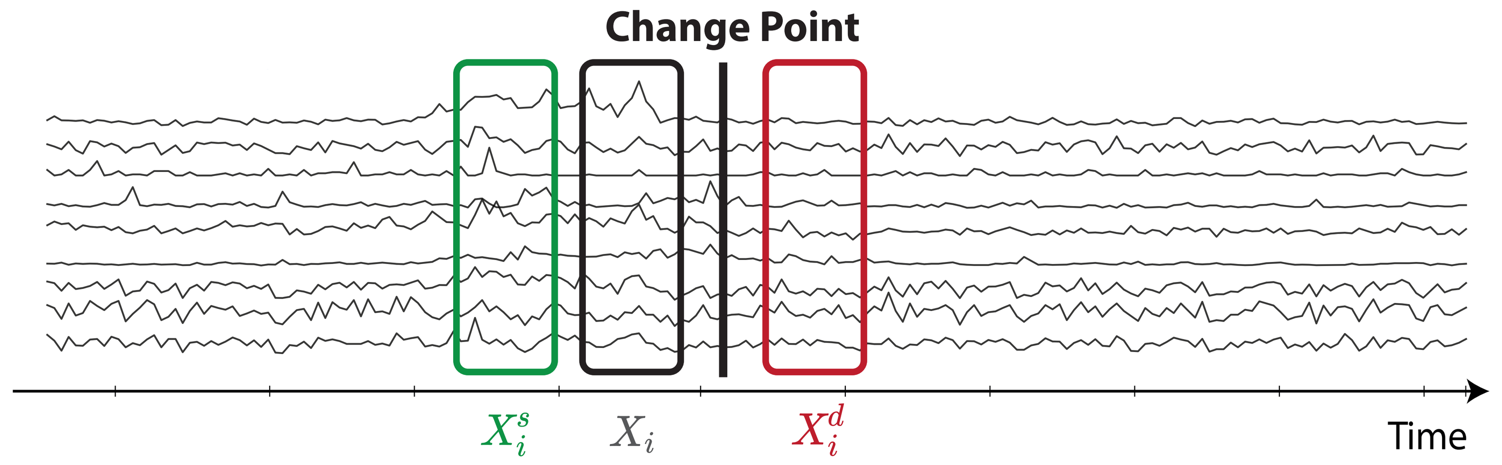
$$\mathcal{S}_{L,\gamma}(X_p^t, X_f^t) > \tau$$

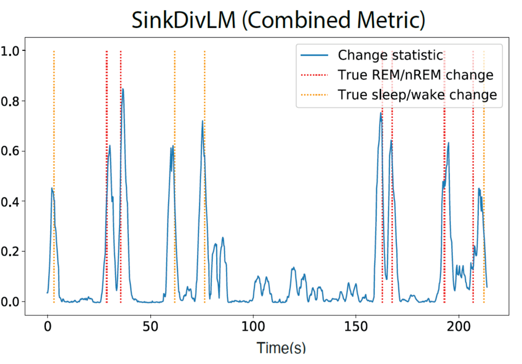
Extension
Learn a metric, for the Sinkhorn divergence computation, that helps to better detect **task-relevant** change points.

1. Select two windows that are both to the right or to the left of the change point: X_i and X_i^s.
2. Select a window that is on the opposite side: X_i^d.
3. Learn a sparse metric (L) by minimizing a triplet loss:

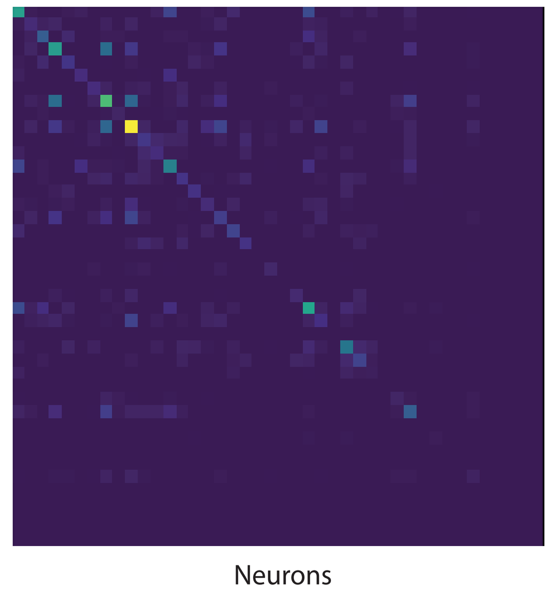
$$l(L) = \sum_{i \in \text{Triplets}} \left[c - \left(\mathcal{S}_{L,\gamma}(X_i, X_i^d) - \mathcal{S}_{L,\gamma}(X_i, X_i^s)\right)\right]^+ + \|L\|_1$$







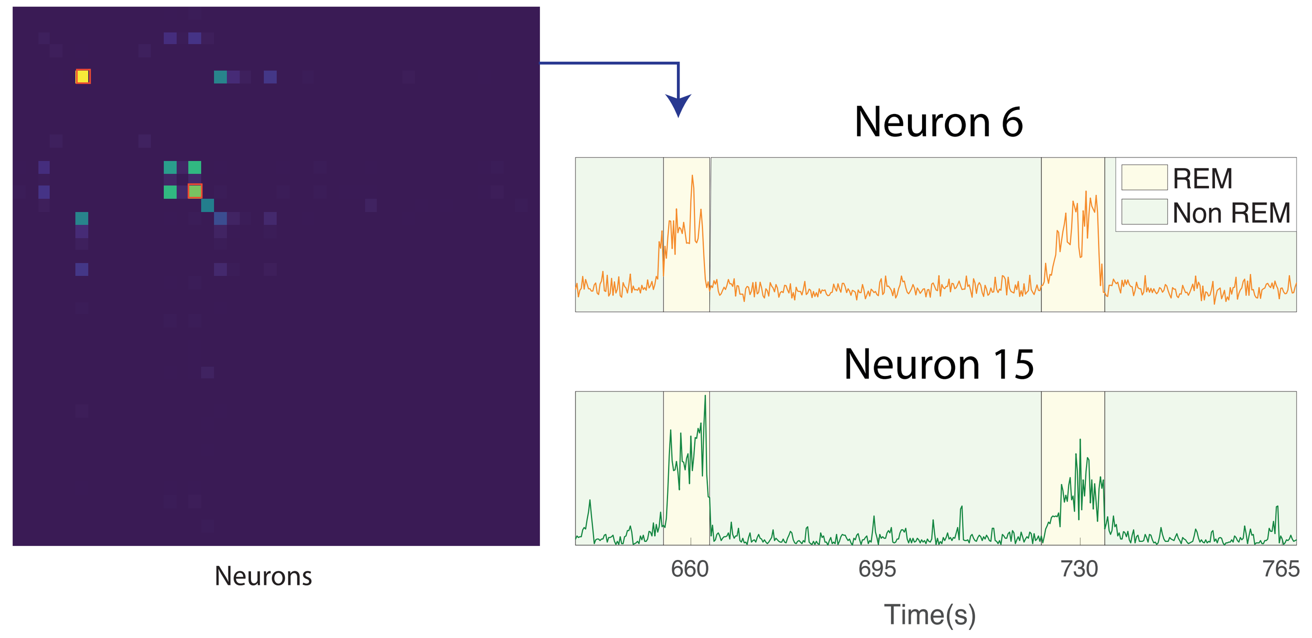
Learned sparse metric
Switch: running/not running



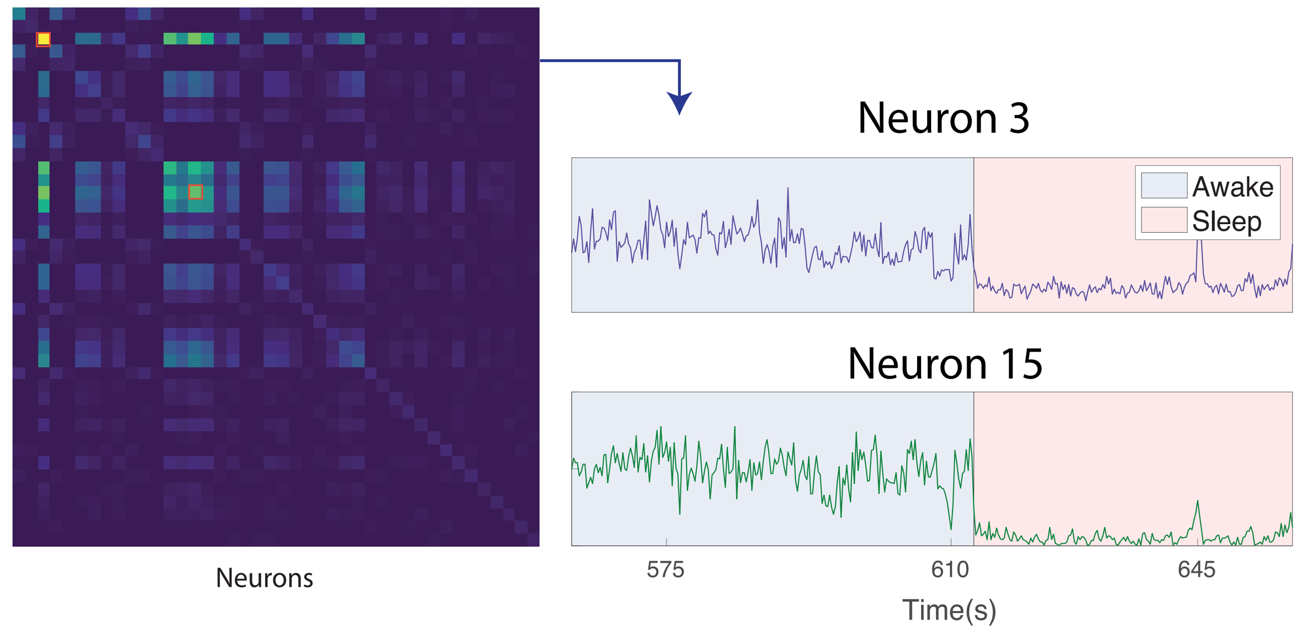
Visualizing the learned metrics

By visualizing the learned metrics, we reveal the most relevant neurons for the identification of a given change point.

Switch: REM/nREM



Switch: sleep/wake



Results

We compare our method **SinkDivLM** with **SinkDiv** (without a learned metric).
We report the AUC of change point detection.

	SinkDiv	SinkDivLM
Trained on sleep/wake		
Sleep/wake	0.58	0.85
REM/nREM/wake	0.79	0.72
Trained on REM/nREM		
REM/nREM	0.92	0.95
REM/nREM/wake	0.79	0.82
Combined sleep metrics		
REM/nREM/wake	0.79	0.85
Trained on running/no running		
Running/no running	0.51	0.65

Conclusion

Our metric learning approach is able to detect the points in which activity switches from one state to another better than the Sinkhorn divergence without this metric and with few labeled instances of change points.

✓ **Improves change point detection**

✓ **Provides interpretability at the scale of neurons**

References and acknowledgements

References:

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