A cortical model for learning complex temporal structure in sensory streams

Subutai Ahmad, Yuwei Cui, and Jeff Hawkins
[sahmad,ycui,jhawkins]@numenta.com
Numenta

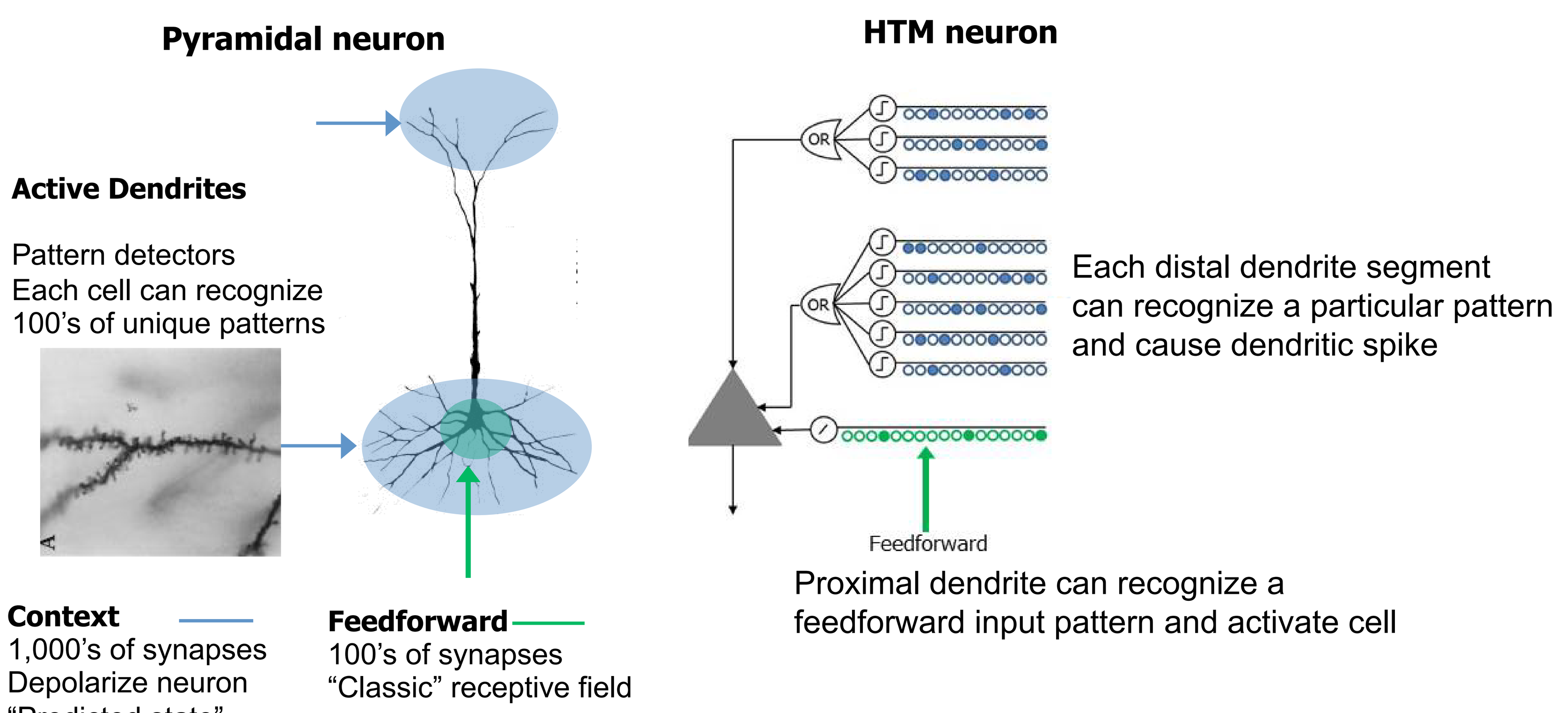
Sequence learning is ubiquitous in cortex

What is neural mechanism for sequence learning?

HTM sequence memory:

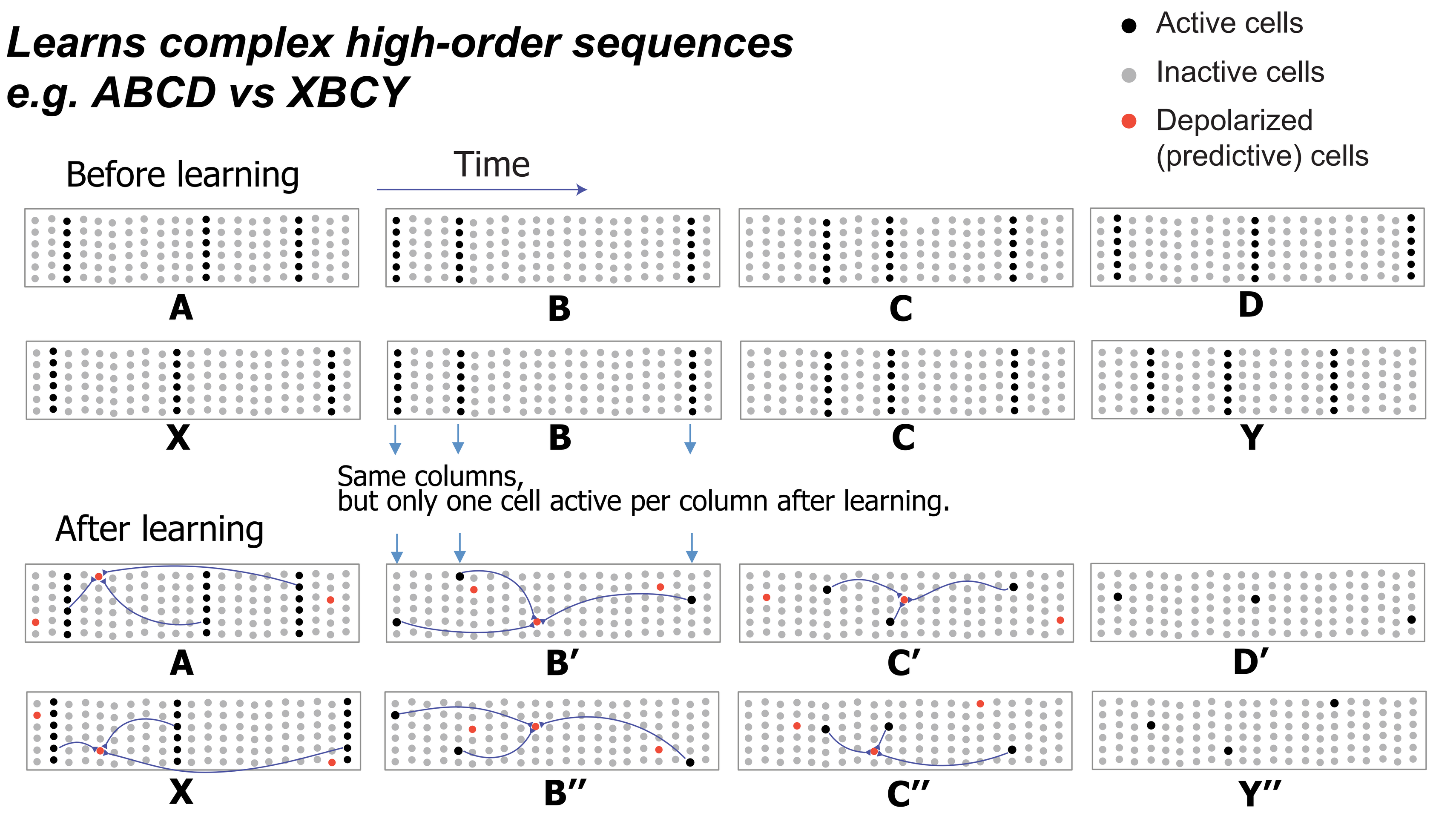
1. Neurons learn to recognize hundreds of patterns using active dendrites.
2. Recognition of patterns act as predictions by depolarizing the cell without generating an immediate action potential.
3. A network of neurons with active dendrites forms a powerful sequence memory.
4. Sparse representations lead to highly robust recognition.
5. Agrees well with experimental evidence.

HTM neuron model:



Experimental support for active dendrites:
Poirazi et al., 2003; Palmer et al., 2014; Major, Larkum and Schiller 2013

HTM network model for sequence learning



Learning and activation rules

Activation rules

- Select the top 2% of columns with strongest inputs on proximal dendrite as active columns
- Detected pattern on distal dendrite causes cell to be depolarized (predicted)
- If any cell in an active column is predicted, only the predicted cells fire
- If no cell in an active column is predicted, all cells in the column fire

Unsupervised Hebbian-like learning rules:

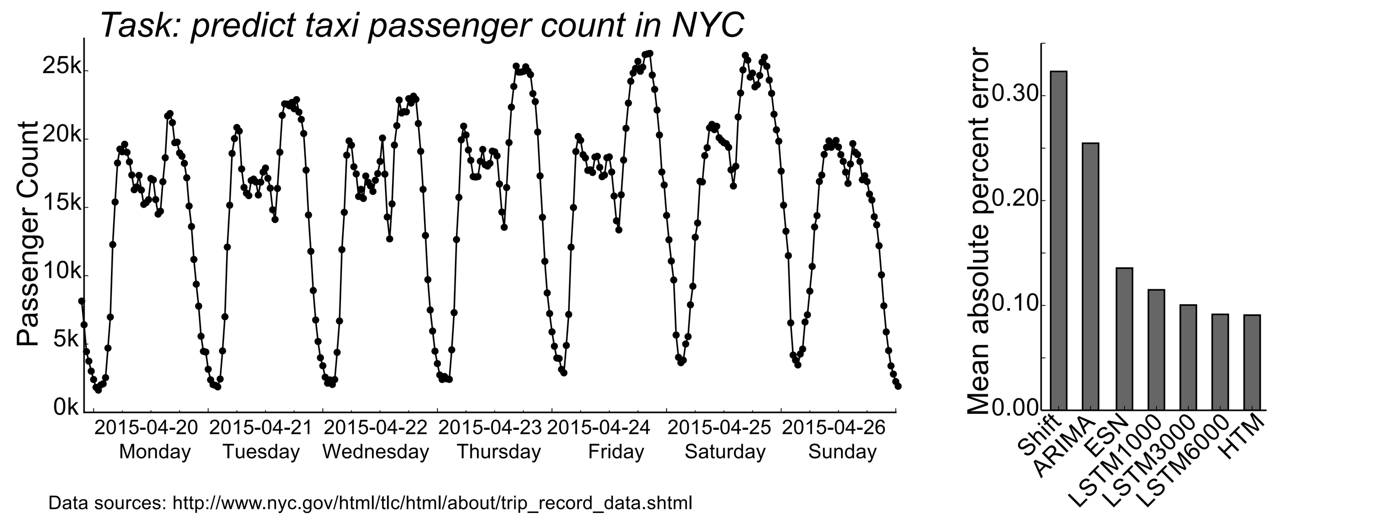
- If a depolarized cell becomes active subsequently, its active dendritic segment will be reinforced
- If a depolarized cell does not become active, we apply a small decay to active segments of that cell
- If no cell in an active column is predicted, the cell with the most activated segment gets reinforced

(Hawkins and Ahmad, 2016)

HTM works well on real-world problems

HTM has comparable performance to state-of-the-art algorithms

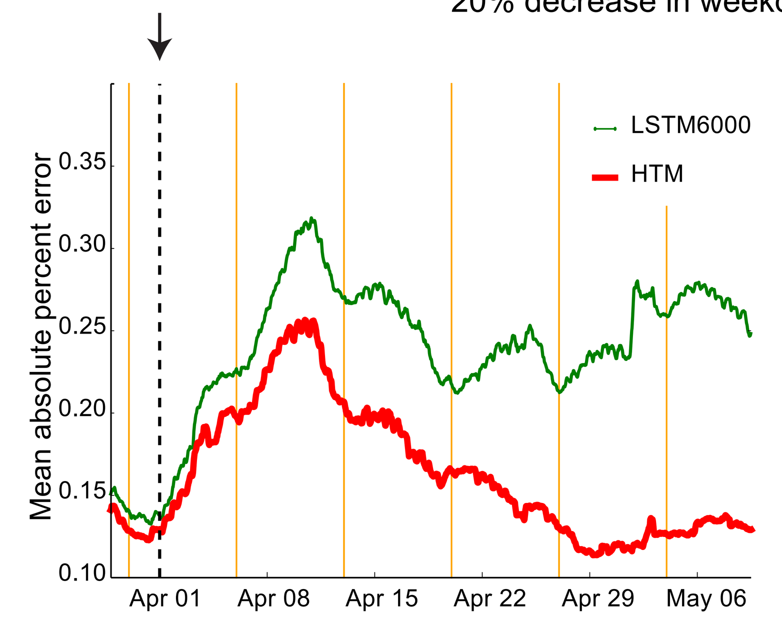
Task: predict taxi passenger count in NYC



(Cui et al., 2016)

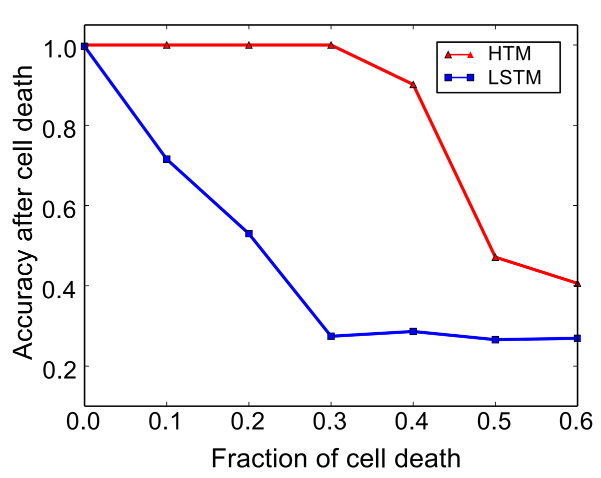
HTM adapts quickly to changes

Injected change to the data
20% increase in weekday night traffic
20% decrease in weekday morning traffic



HTM adapts quickly to changes in statistics due to its continuous unsupervised Hebbian learning rule.

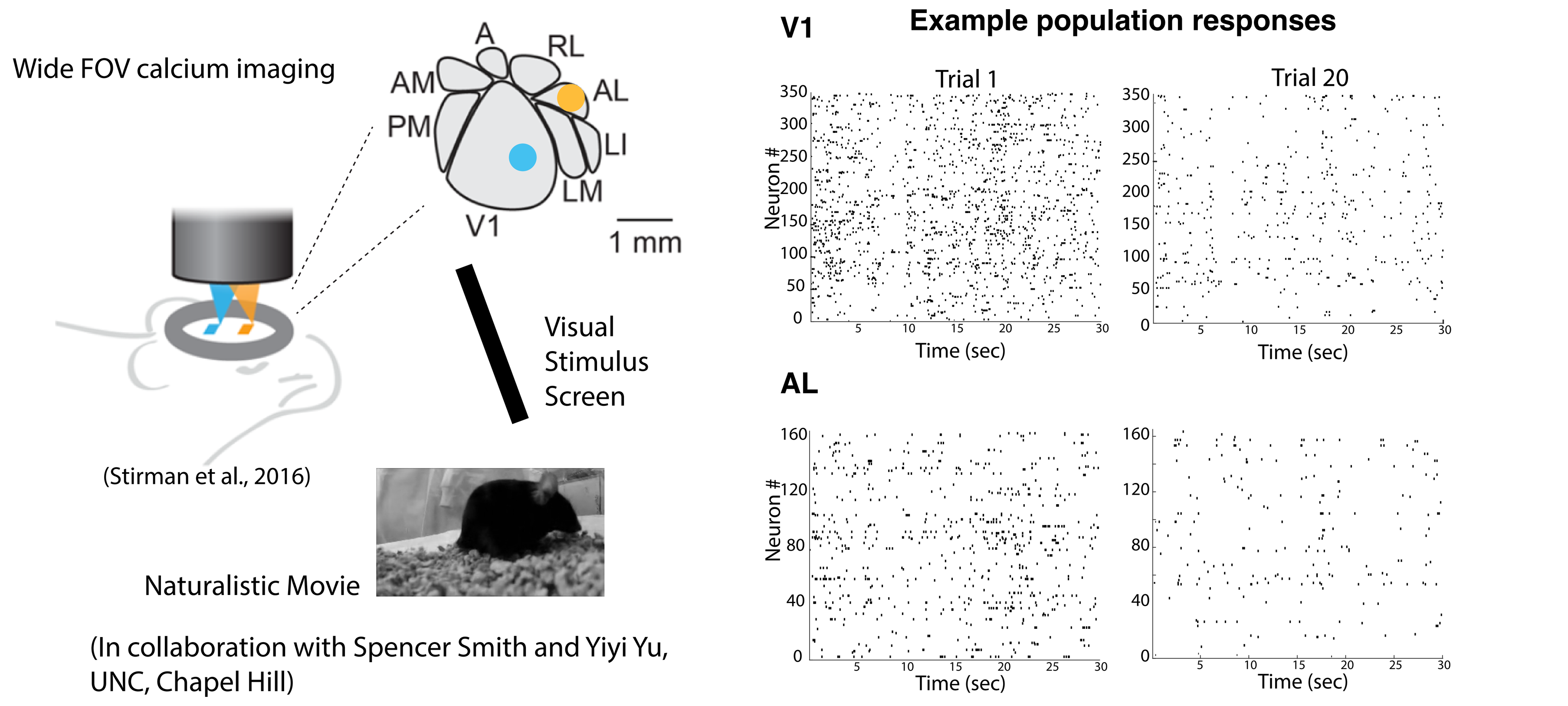
HTM exhibits high fault tolerance to neuron death



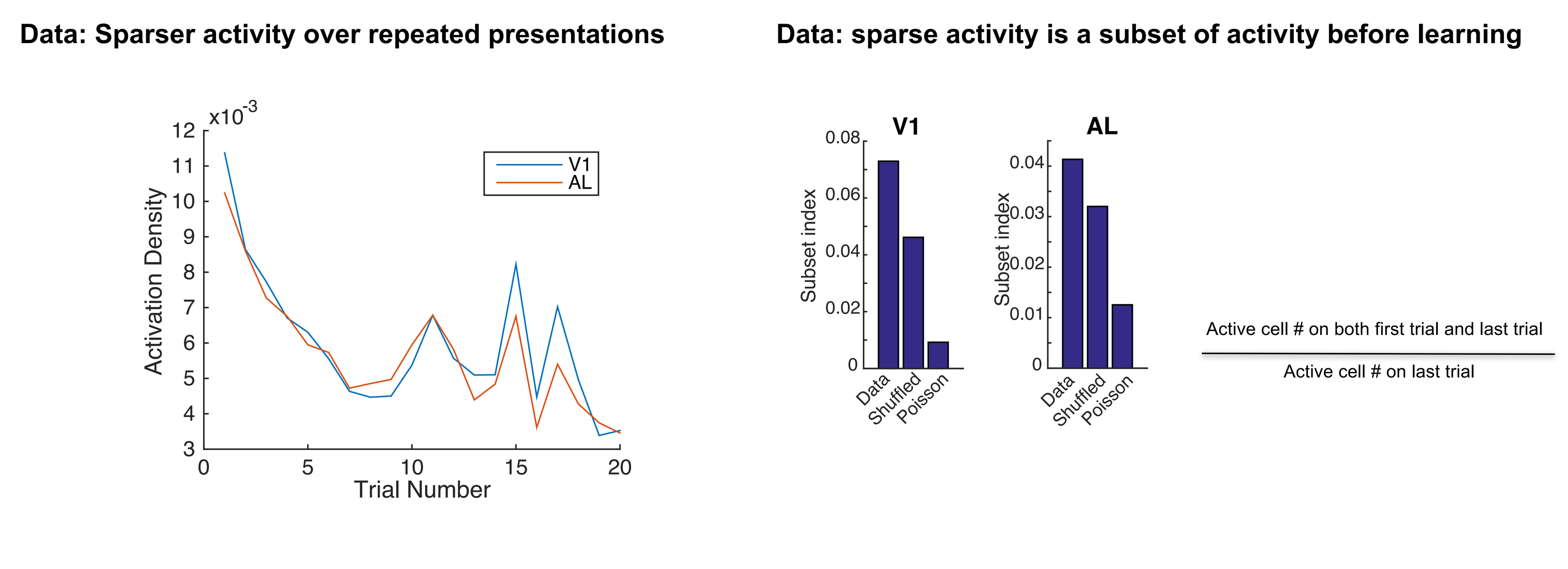
HTM is fault tolerant due to properties of sparse distributed representations (Hawkins & Ahmad 2016).

In contrast, LSTM and most other artificial neural networks are sensitive to loss of neurons or synapses (Piuri 2001).

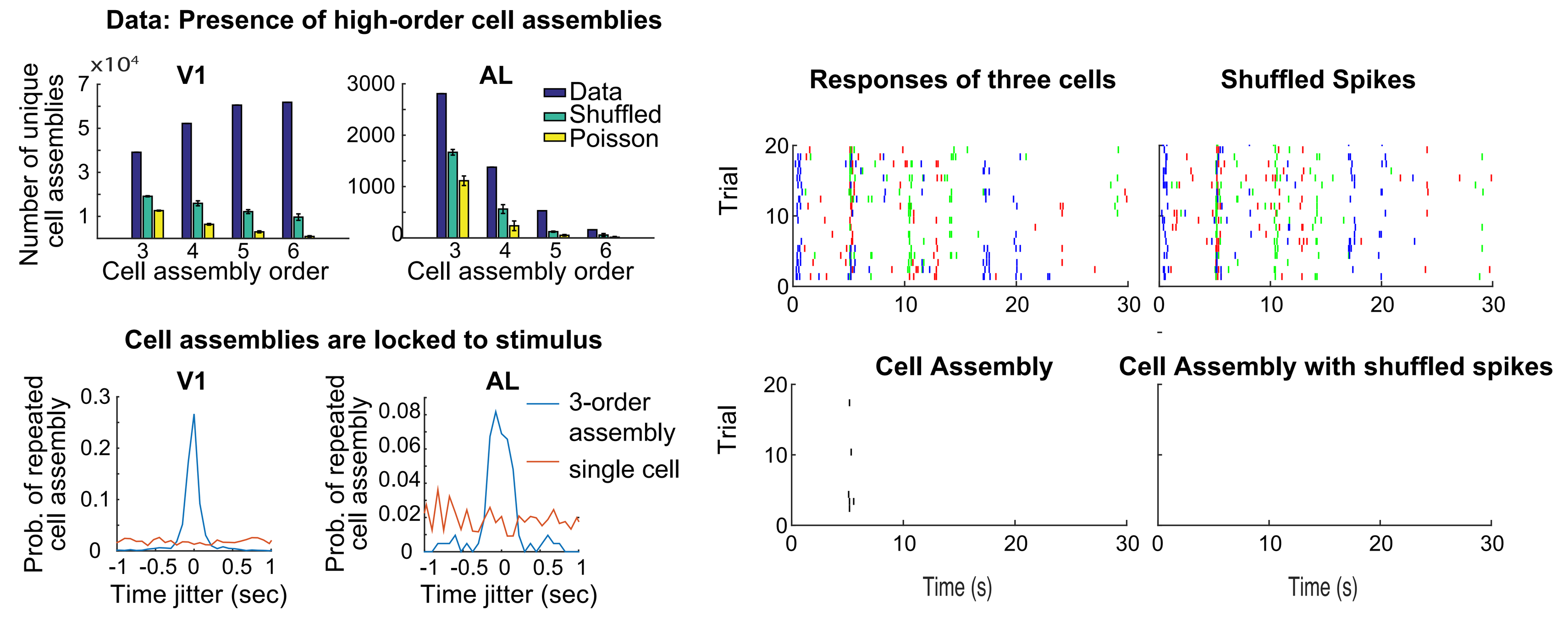
Testable predictions and experimental validation



HTM sequence memory predicts structured sparser activity for learned sequence



HTM sequence memory predicts presence of high-order cell assemblies



References

Cui Y, Ahmad S, Hawkins J. Neural Computation. (2016) 28: 2474-2504
Hawkins J, Ahmad S, Front. Neural Circuits. 10 (2016) 1–13.
Major, G., Larkum, M. E., and Schiller, J. (2013). Annu. Rev. Neurosci. 36, 1–24.
Miller JK, Ayzenshtat I, Carrillo-Reid L, Yuste R (2014). PNAS 111(38):E4053-61
Piuri, V., J Parallel Distr Com., vol. 61, pp. 18-48.
Poirazi P, Brannon T, Mel BW (2003) Neuron 37:989–999.
Stirman, J. N., Smith, I. T., Kudenov, M. W. & Smith, S. L. (2016) Nat. Biotechnol. 34, 857–862.