Compressed Temporal Representation During Visual Paired Associate Task in Monkey Prefrontal Cortex and Hippocampus

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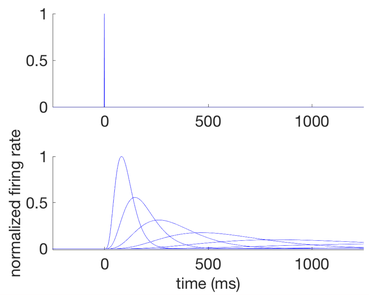
Background

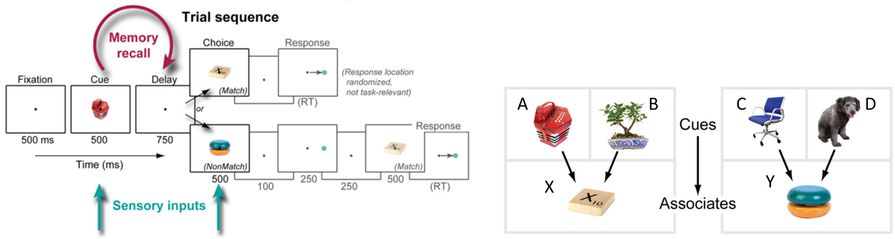
- Our model of memory depends on representations of a compressed temporal history
- Time cells could support such a representation
- Time cells have been extensively identified and characterized in rodent HPC
- We identify stimulus selective time cells in monkey PFC and HPC in a visual working memory paired associate task

Ideal Time Cells[2,3]



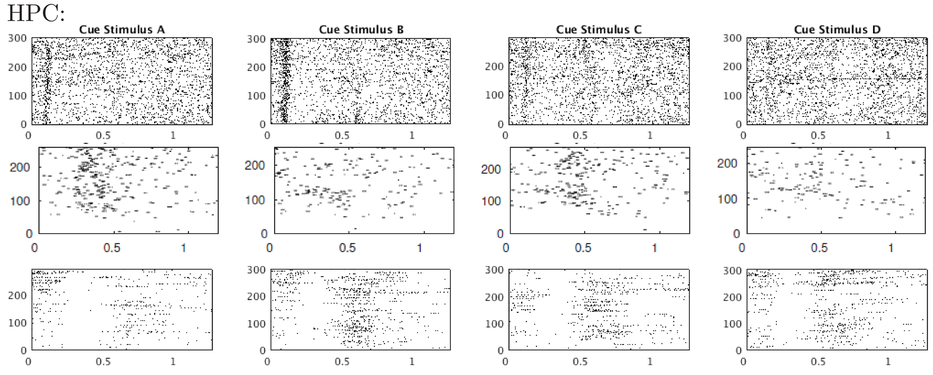
Experiment Used Visual Stimuli[1]

This experiment featured a paired associate learning task with a 1.25 second delay between initial stimulus presentation and the associate stimuli.

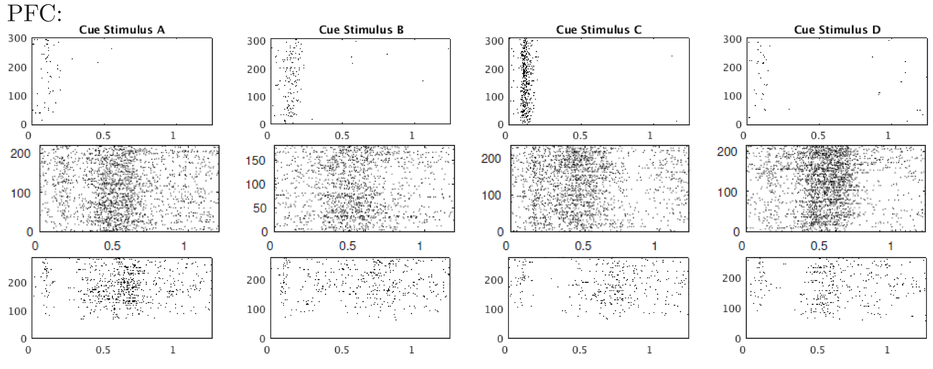


Example Time Cells

HPC:



PFC:



Modeling

We used a maximum likelihood estimation with a Gaussian model of time cells.

ML minimization: $\arg\min_\Theta \mathrm{nLL} = -\sum_{\mathrm{trial}} \sum_t [f_t \ \log(p(t;\Theta)) + (1-f_t)\log(1-p(t;\Theta))]$

Time Cell approximation: $T(t;\sigma_t,\mu_t) = e^{\frac{-(t-\mu_t)^2}{2\sigma_t^2}}$

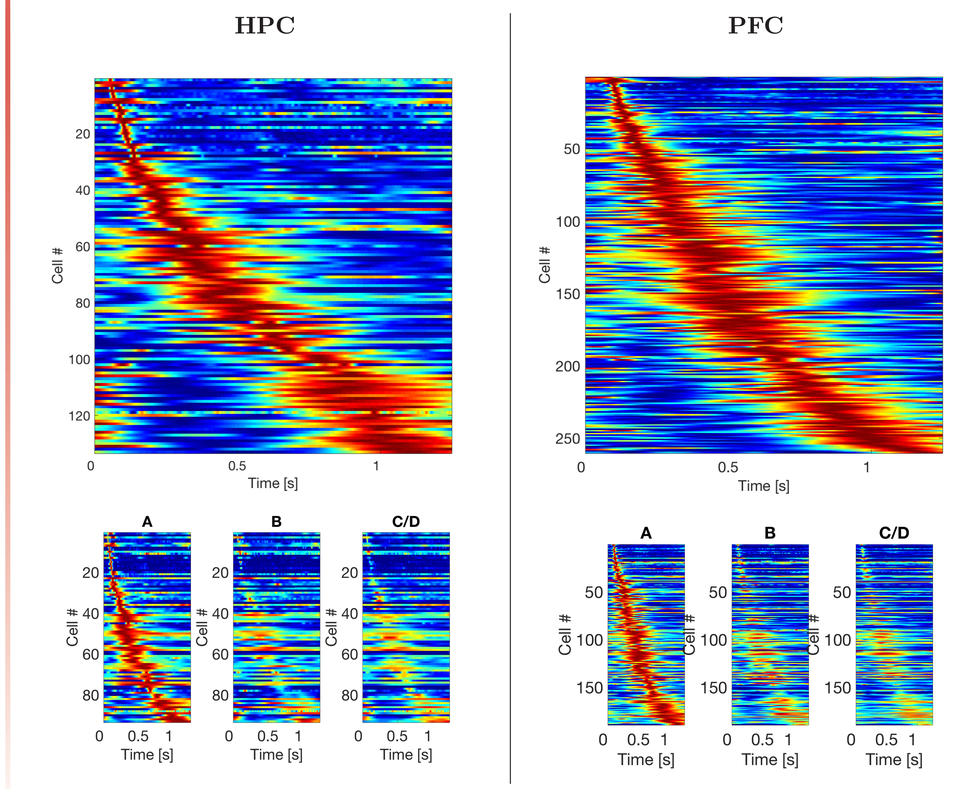
Constant Model: $p\,(t;\Theta) = a_0$

Time Cell Model: $p\,(t;\Theta) = a_0 + a_1 T(t;\sigma_t,\mu_t)$

Stimulus Specific Model: $p\,(t;\Theta) = a_0 + \sum_{i=1}^{4} a_i c_i T(t;\sigma_t,\mu_t)$

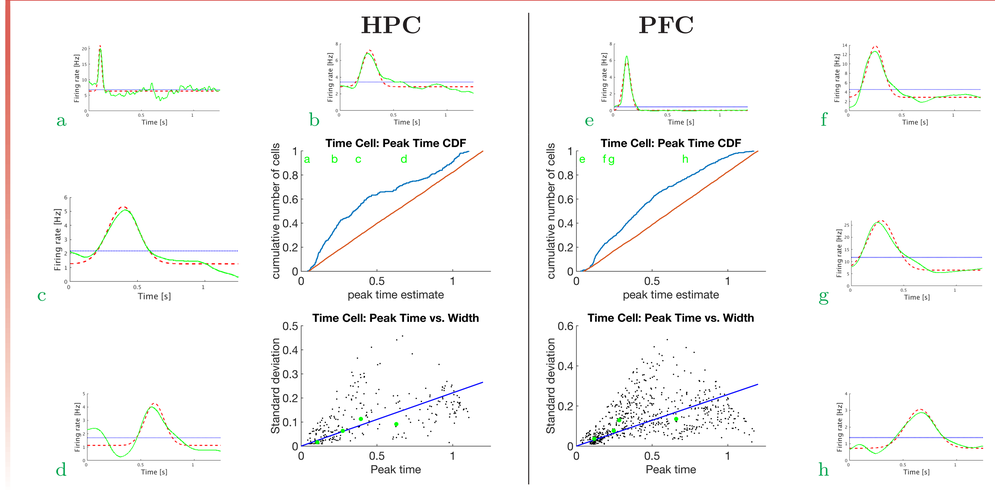
Paired Stimuli: $p\,(t;\Theta) = a_0 + \sum_{i=1}^{2} a_i c_i T(t;\sigma_t,\mu_t)$

HPC and PFC Show a Temporal History

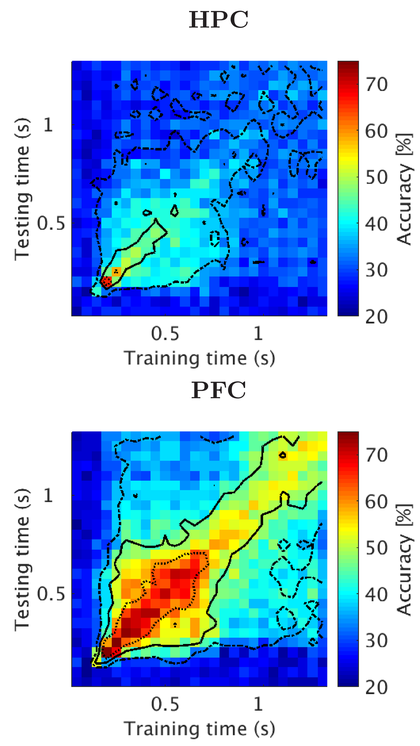


The time cells are stimulus selective, but not selective for predictive categories.

Temporal History is Compressed



LDA



Results

These time cells

- Exist in both PFC and HPC
- Encode Visual Stimulus Identity
- Are organized into a compressed representation
- Code for past, not future

References

[1] Scott L. Brincat, and Earl K. Miller. *Frequency-specific hippocampal-prefrontal interactions during associative learning.* Nature neuroscience 18.4 (2015): 576-581.

[2] K. H. Shankar and M. W. Howard. *A scale-invariant representation of time.* Neural Computation, 2012.

[3] Zoran Tiganj, Jason A Cromer, Jefferson E Roy, Earl K Miller, Marc W Howard. *Compressed timeline of recent experience in monkey lPFC.* bioRxiv, 2017

Acknowledgments

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