BOSTON UNIVERSITY

Poster: E82

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Time Cell Population from Various Delays Show Similar Structures

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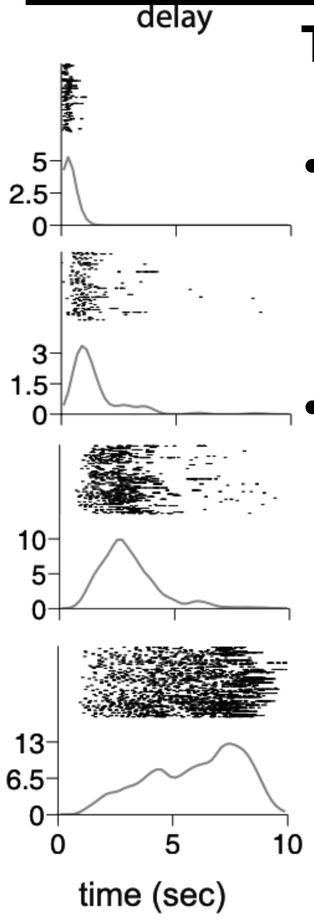
Episodic Memory is Compressed as Time Goes by

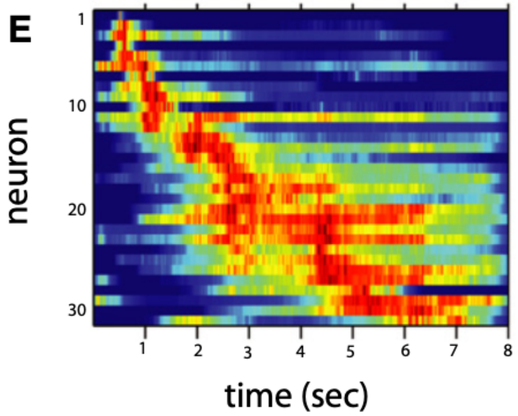
Time cell: temporal selectivity



MacDonald et al. 2011

Time Cell:

- Sequentially activated cells after event onset
  - Temporal information can be decoded through time cells
- Each cell has a temporal receptive field (time-field)
  - Center: when the cell most active
  - Width: measures the selectiveness



Compression at neural level

- **Compression happens in 2 ways:**
  - More time cells fire shortly after the event; fewer time cells fire when the event fades into the past
  - Early time cells are very selective; late time cells have wider time-fields
- In current study, we observed similar compression across multiple time cell data sets despite different delays.
- Through Hierarchical Bayesian method, we learned that compression is unlikely to be a simple trial-averaging effect but happens at both within and between trial level

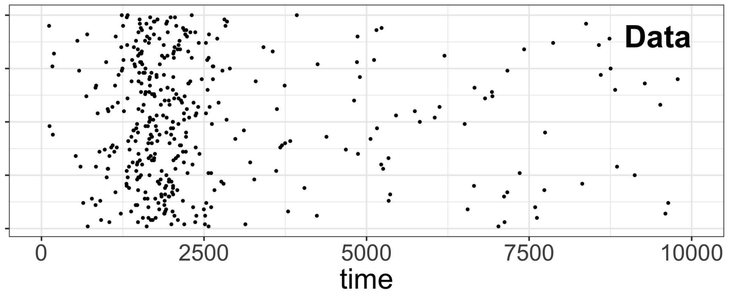
Investigate the compression through Hierarchical Bayesian

Hierarchical Bayesian Model

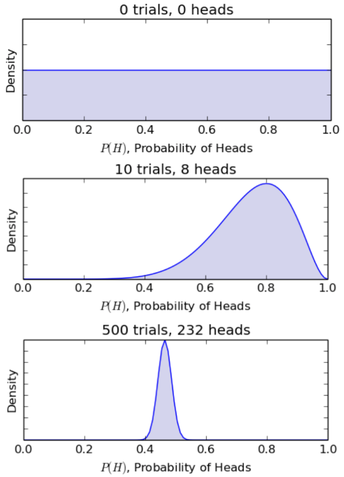
- **Bayes' rule**

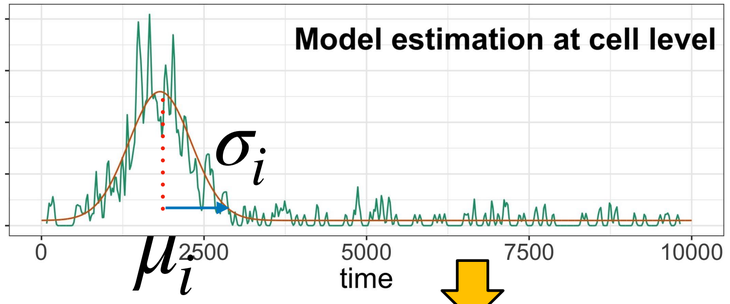
$$P(\theta \mid D) = \frac{P(D \mid \theta)P(\theta)}{P(D)}$$

Posterior | Likelihood | Prior



- **Redistribution of belief**

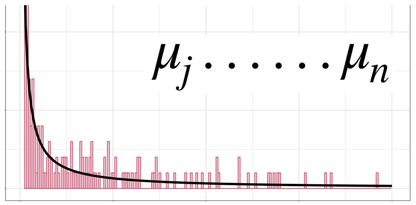




α **controls the skewness of time cell population:**

- α >0: time cells are not uniformly distributed
- Bigger α = More cell fire early

$$\mu \sim Powerlaw(x_{min}, x_{max}, \alpha)$$

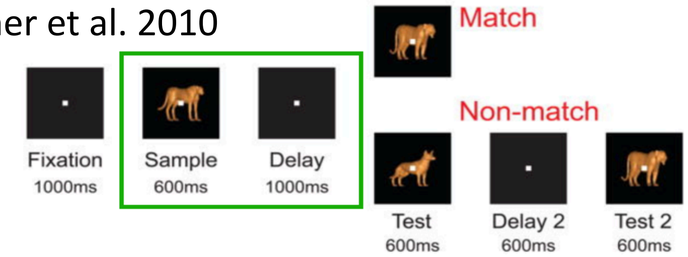


- **Hierarchical Hyper-parameters: belief about the parameters**

Time cell populations from different delay/region/animal

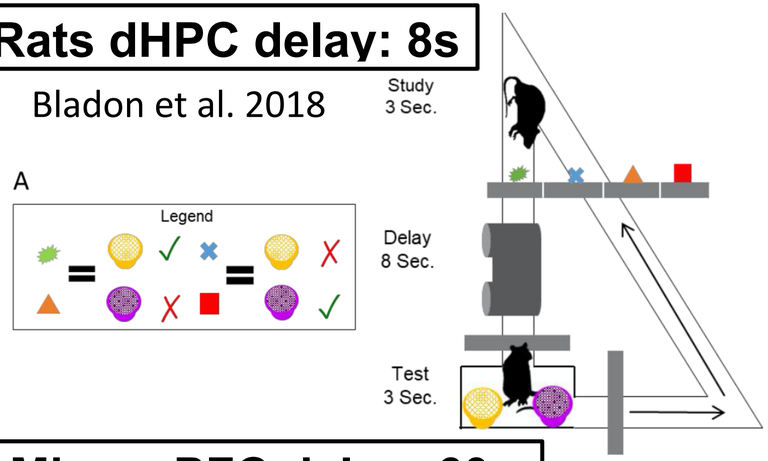
Monkeys lPFC delay: 1.6s

Cromer et al. 2010

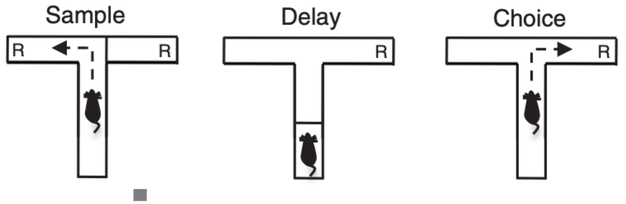


Rats dHPC delay: 8s

Bladon et al. 2018

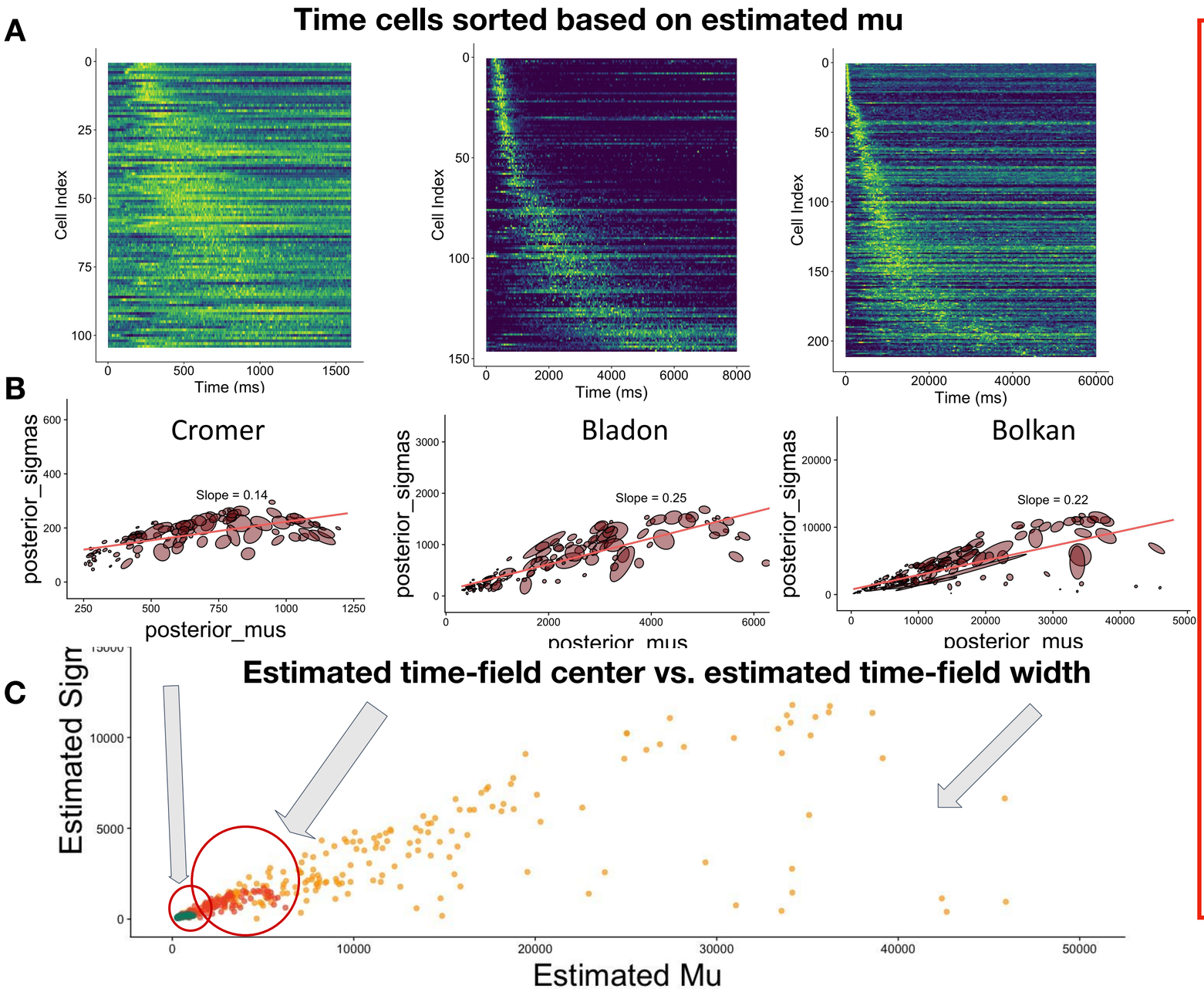


Mice mPFC delay: 60s



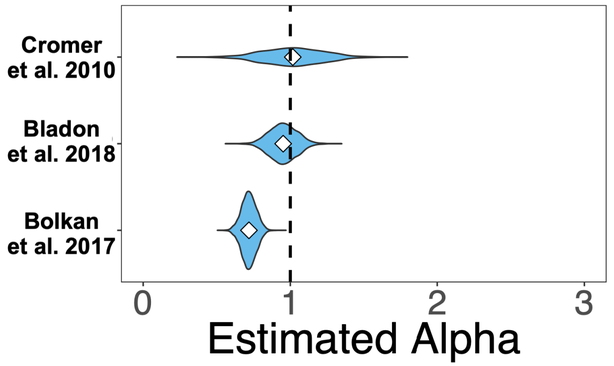
Bolkan et al. 2017

Striking similarity between the time cell populations



Results

- **More time cells fire for early delay than late in all 3 data sets**
  - 0 is excluded



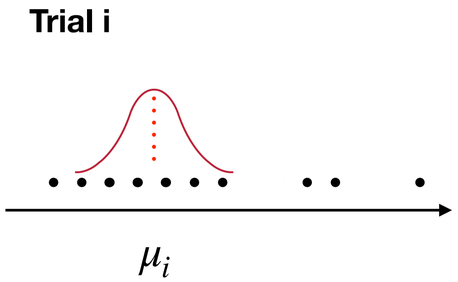
- **Time-field width increases for later time cells**
  - Width increases at similar rate across 3 data sets despite different delays
  - **Trial averaging Effect?**

Model within-trial time-field width and between-trial variability separetly

Model Assumptions:

- For each trial, the time cell fires mostly at the normal tuning curve + some random firing (uniform)

$$spike(t) = a_1 Normal(\mu_i, \sigma_w) + (1 - a_1) Uniform$$

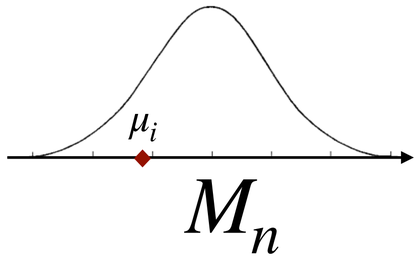


- The the time-field shift (early or late) from trial to trial

$$\mu_i \sim Normal(M_n, \sigma_t)$$

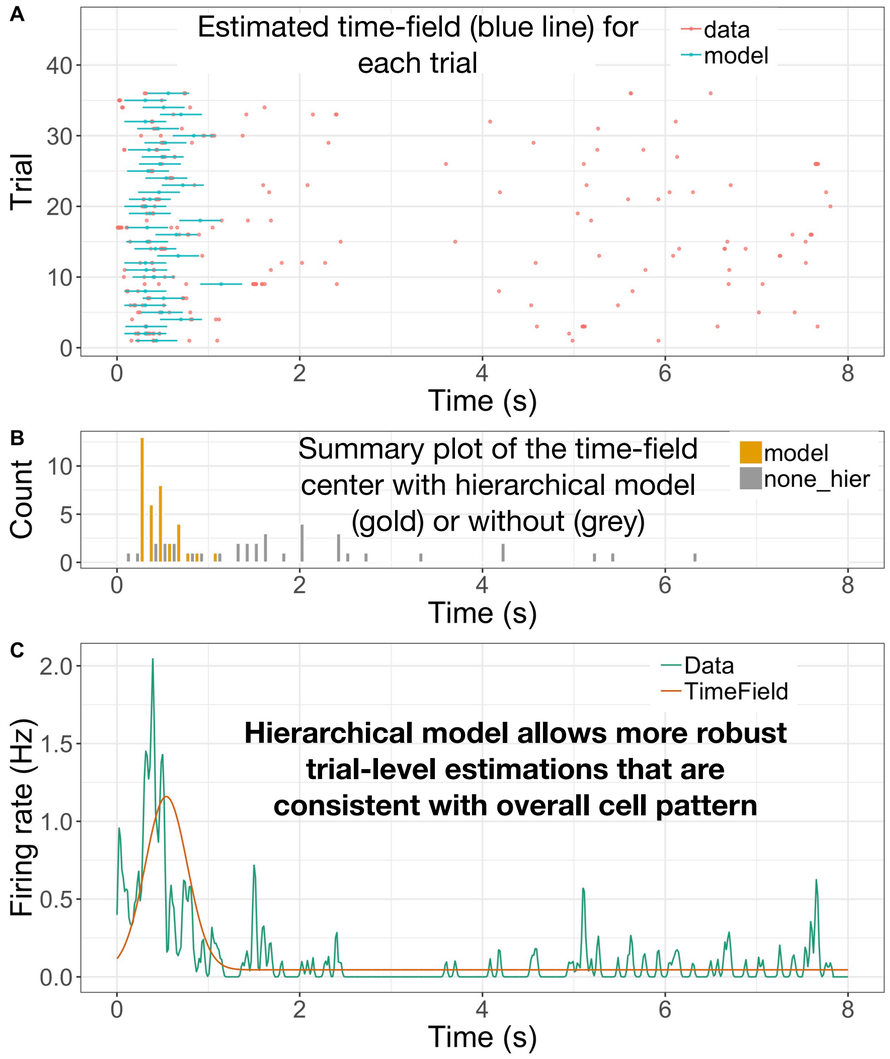
- σ_w: quantifies trial-level selectiveness

σ_t : quantifies consistency across trials

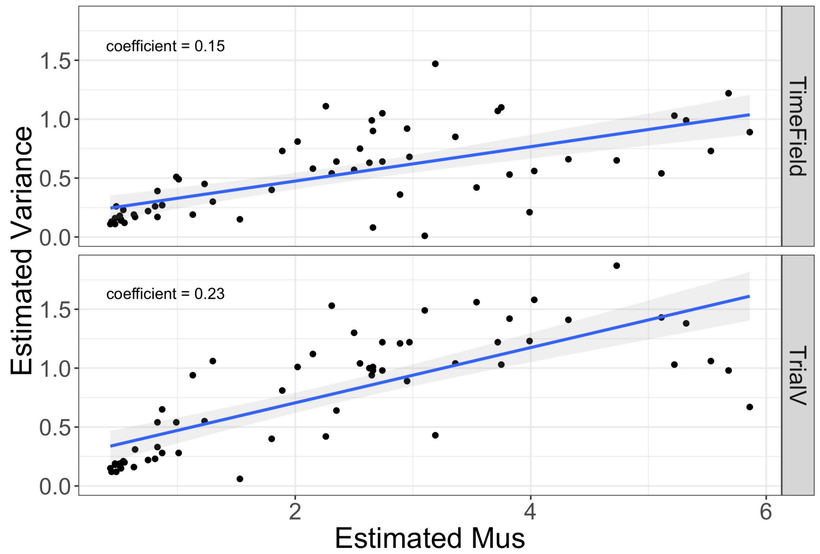


Experiment:

- **8 Rats in pair-association tasks with 8s delay; single-unit dHPC (Bladon et. al., 2018)**



Time-field width increases for later cells: Not just trial-averaging effect

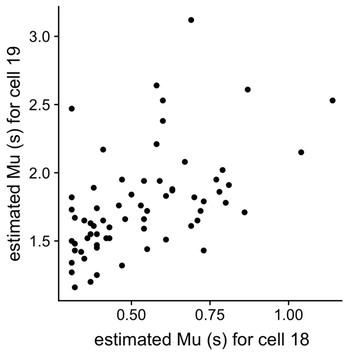


Top: estimated time field center vs. width; Bottom: estimated time-field center vs. between-trial consistency

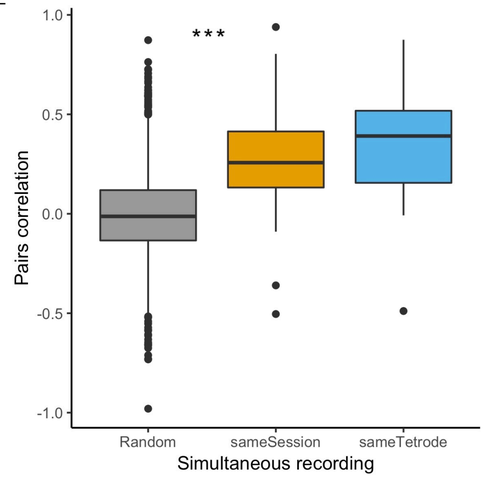
The temporal uncertainty increased as delay continues

- **Within-trial level: time-field width increases**
- **Between-trial level: time-field shift more from trial to trial**

Simultaneously recorded cells correlate with each other



Each point represent a trial: x and y corresponding to the estimated mus of the trial for simultaneously recorded cell pair (cell 18 and 19). In trials where cell 18 fires relatively late, cell 19 is also likely to fire relatively late and vice versa, results in high correlation.



- **The between-trial shift is not random but coordinated**
  - Significantly higher correlation between simultaneously recorded pairs (sameSession and sameTetrode) than random pairs.
  - Could be due to internal or external cues

Future Direction

- **Incorporate the trial-level estimation for all data sets and investigate the skewness of time cell distribution**
- **Test different assumptions of time field population distributions**

Reference List:

Bladon, J. H., Ning, W., Werneck, L., Marino, F., Liu, C., Howard, M. W., Coding of What and When in Lateral Entorhinal Cortex and Hippocampus during a Delayed Matching Task [poster presentation]. *SfN 2018 Conference,* San Diego, CA, United States

Bolkan, S. S., Stujenske, J. M., Parnaudeau, S., Spellman, T. J., Rauffenbart, C., Abbas, A. I., & Kellendonk, C. (2017). Thalamic projections sustain prefrontal activity during working memory maintenance. *Nature neuroscience*, *20*(7), 987.

Cromer, J. A., Roy, J. E., & Miller, E. K. (2010). Representation of multiple, independent categories in the primate prefrontal cortex. *Neuron*, *66*(5), 796-807.

MacDonald, C. J., Lepage, K. Q., Eden, U. T., & Eichenbaum, H. (2011). Hippocampal “time cells” bridge the gap in memory for discontiguous events. *Neuron*, *71*(4), 737-749.

Rakitin, B. C., Gibbon, J., Penney, T. B., Malapani, C., Hinton, S. C., & Meck, W. H. (1998). Scalar expectancy theory and peak-interval timing in humans. *Journal of Experimental Ps*Funding:

Funding: NIMH R01MH112169; NIMH R01MH095297; NIBIB R01EB022864

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