Neural Substrates of Memory and Prospection

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Expected Properties of Memory-Related Activity

- ❑ Time-compressed.
- ❑ Contributes to representing future possibilities.
- ❑ Related to behavioral decisions.

Memory and Planning

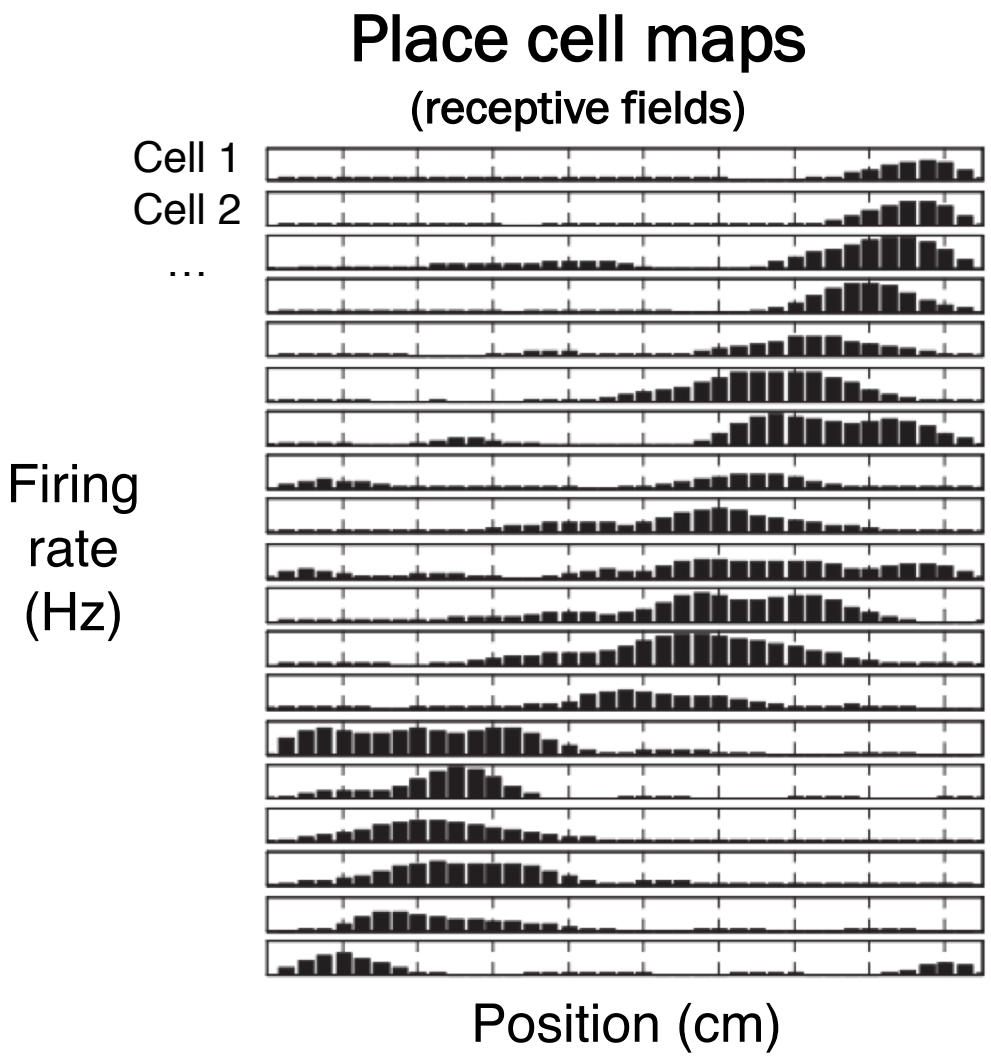
- Memories allow past experience to inform future decisions.

- Prospection based on SWRs would be limited to behavioral states where SWRs are seen (immobility and slow movement).

- Question:
  - Are there other forms of non-local activity that could inform decision-making processes?

Kenny Kay

Hippocampal Theta Sequences



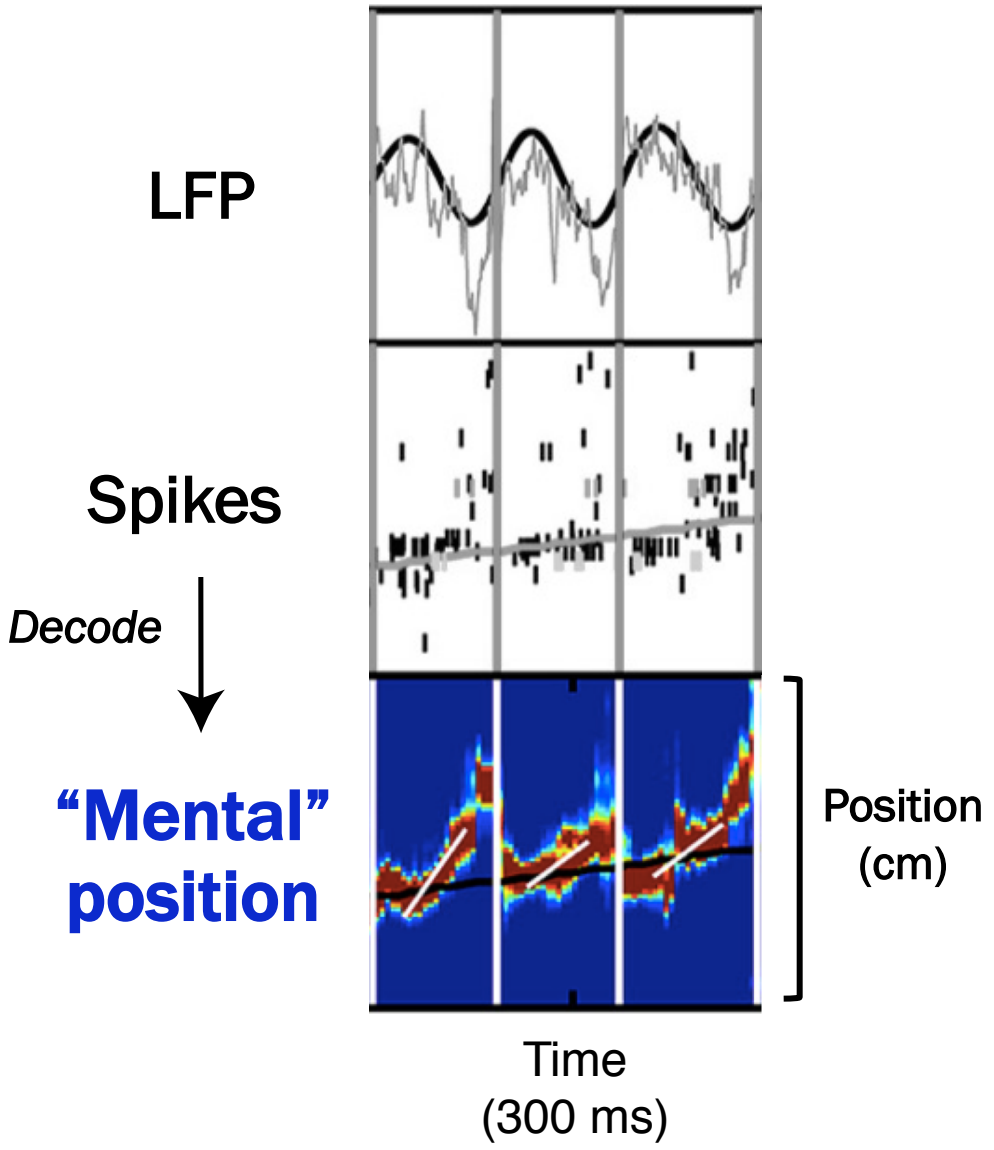


Figure from Feng & Foster (2015)

Hippocampal Theta Sequences

= Population firing sequences that encode sequences in space

Each sequence lasts ~100 ms.

LFP

Spikes

“Mental” position

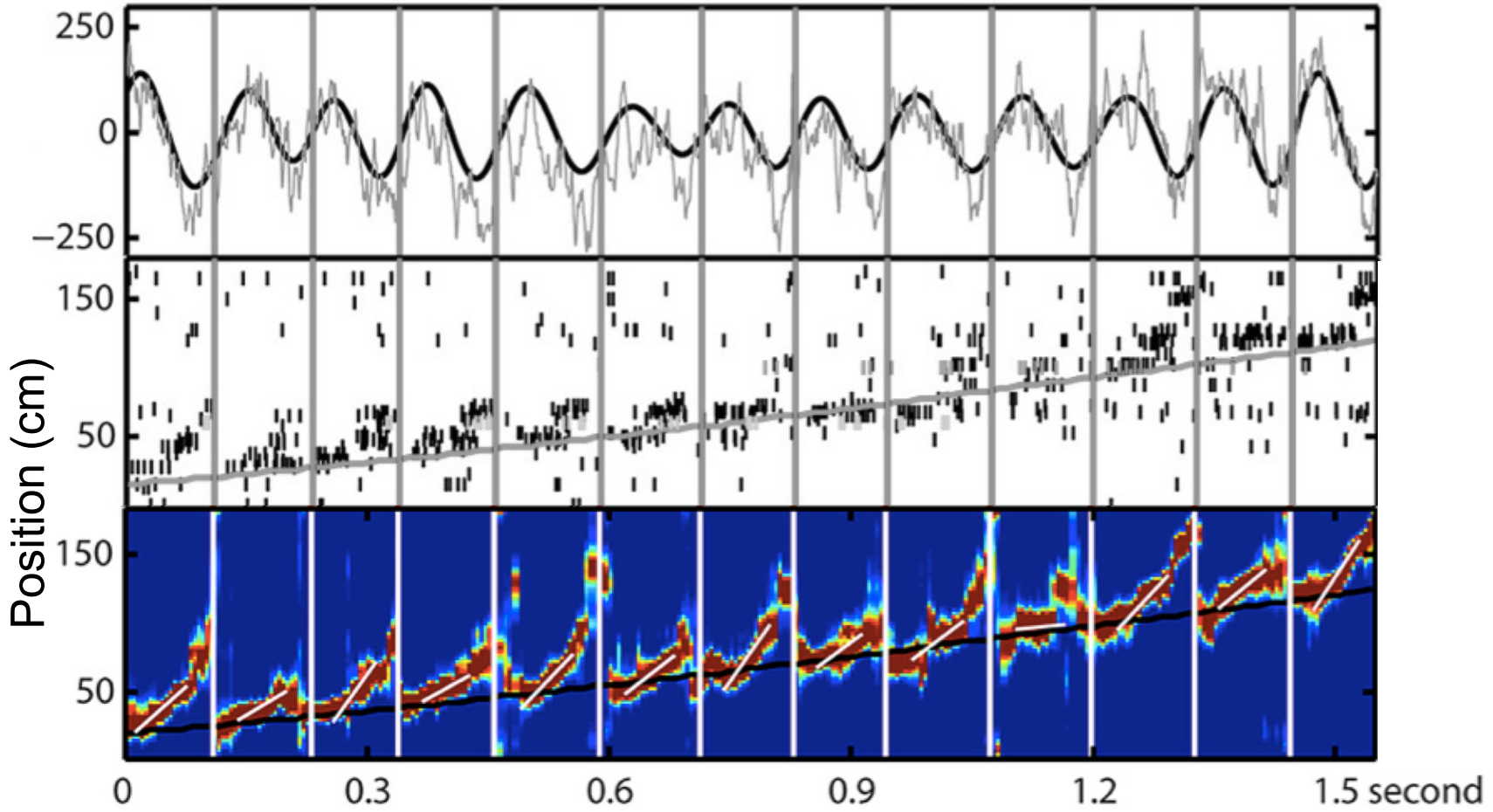
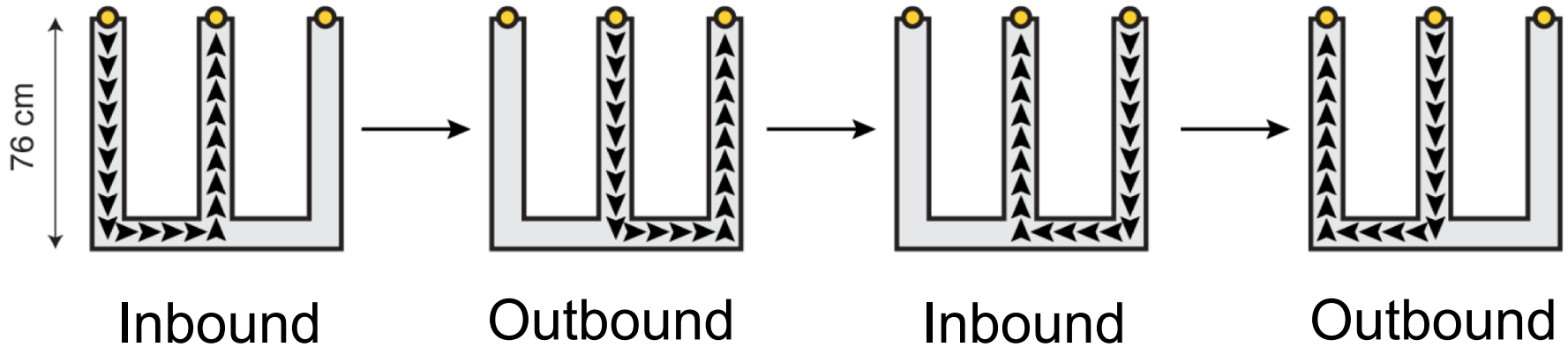


Figure from Feng & Foster (2015)

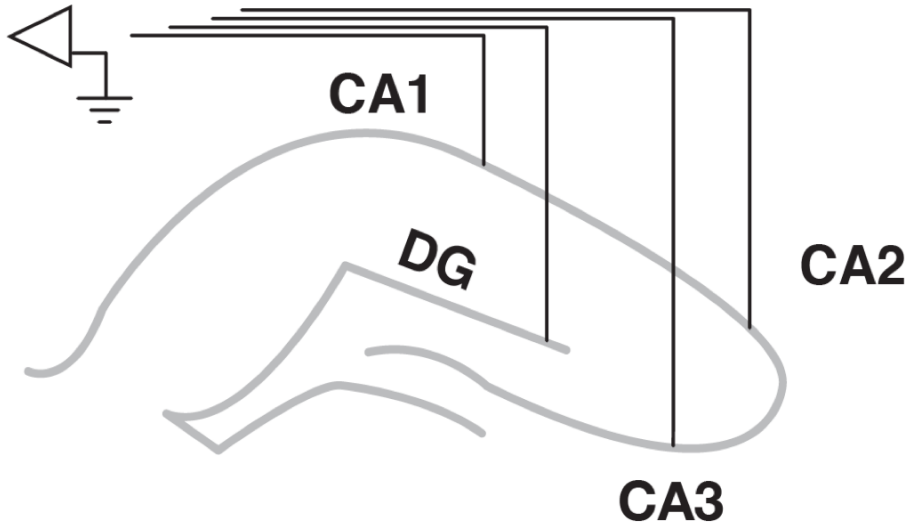
Spiking During Hippocampal Theta Sequences

- ☑ Time-compressed.
- ❑ Capable of representing future possibilities?

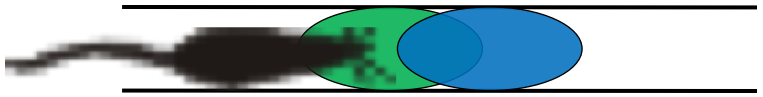
Continuous Alternation Task and Regional Targeting

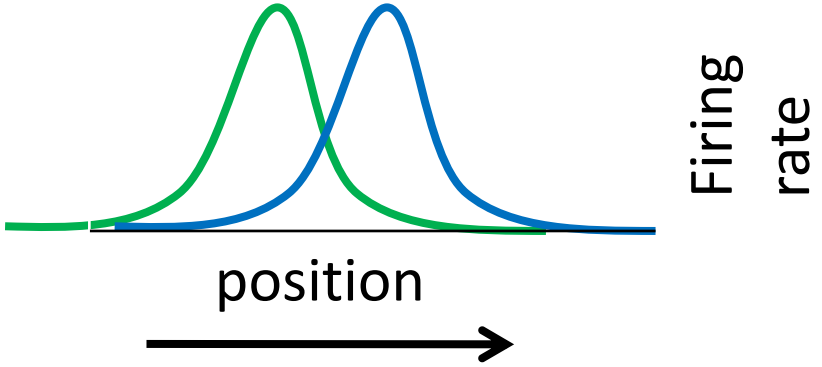


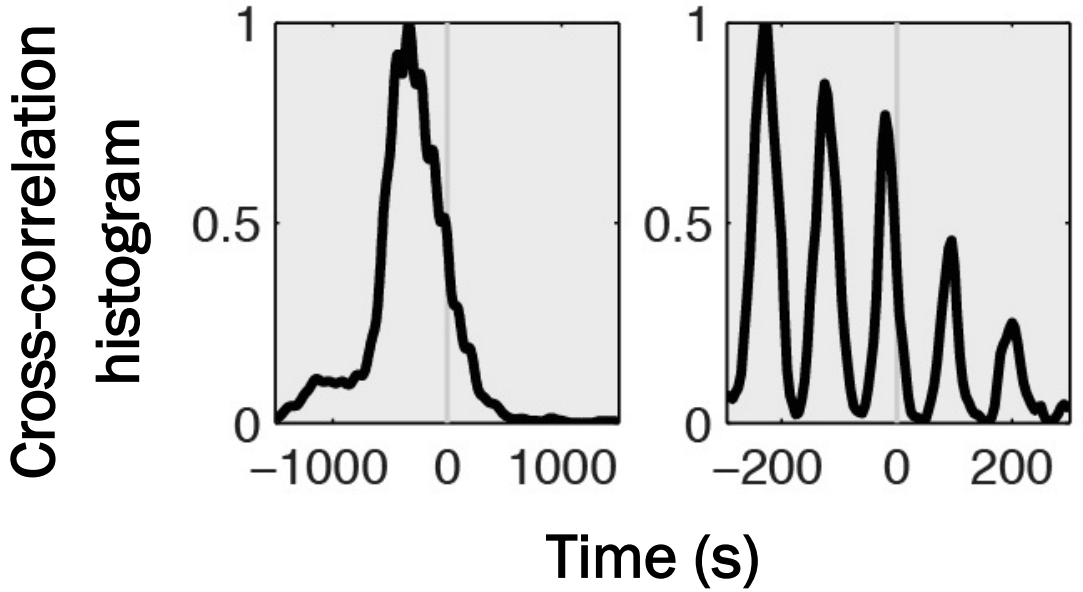
Outbound trials require memory of previous outbound choice



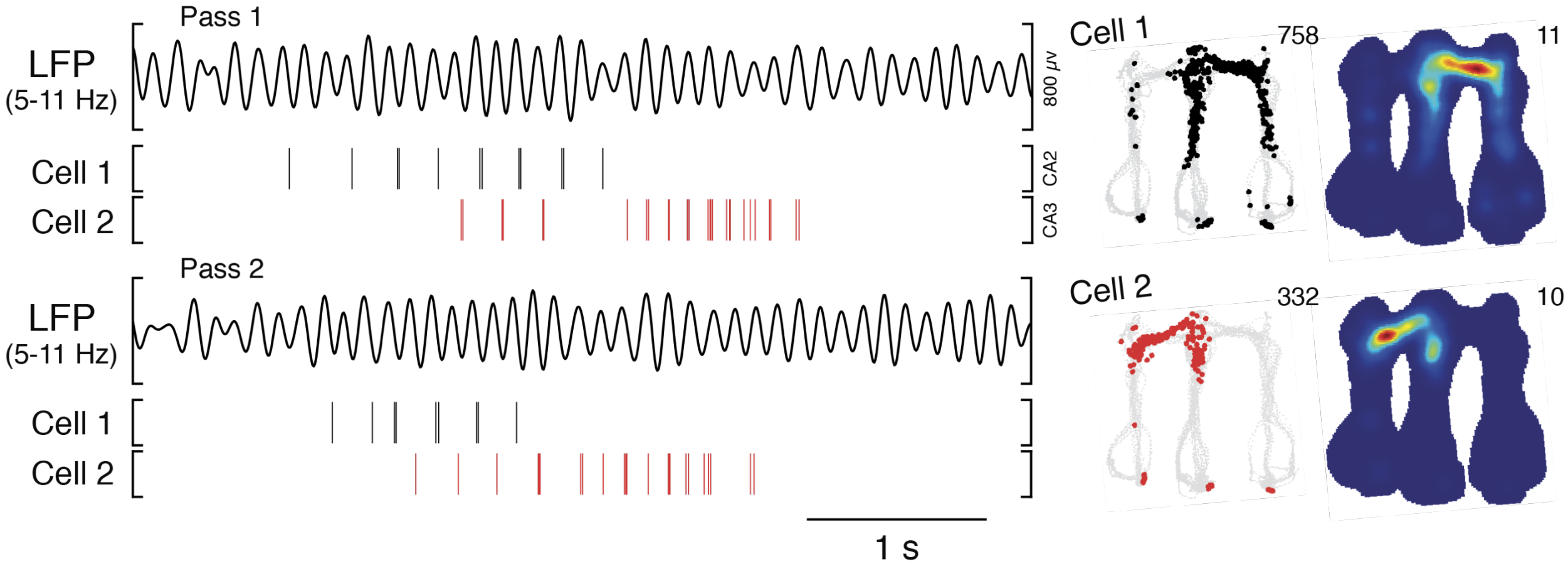
Expected Co-firing Patterns





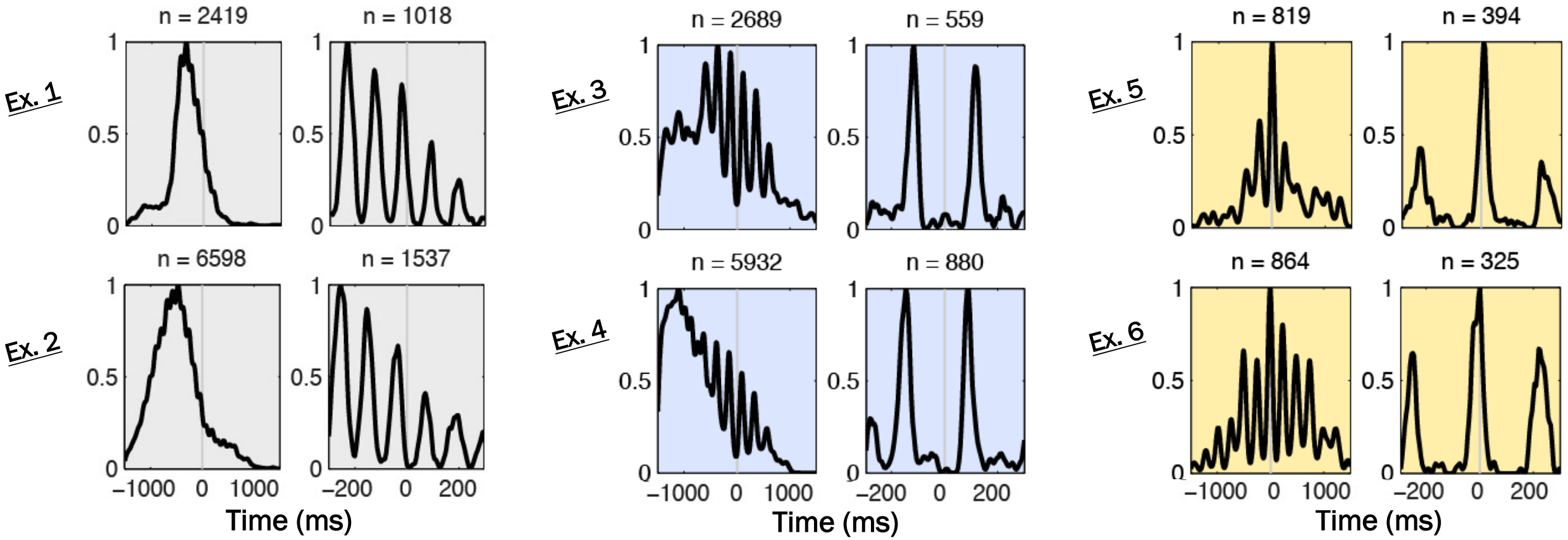


Observed Co-firing Patterns (in a subset of pairs)



Example 1

Normal, Anti-synchronous and Synchronous Pairs



~66%

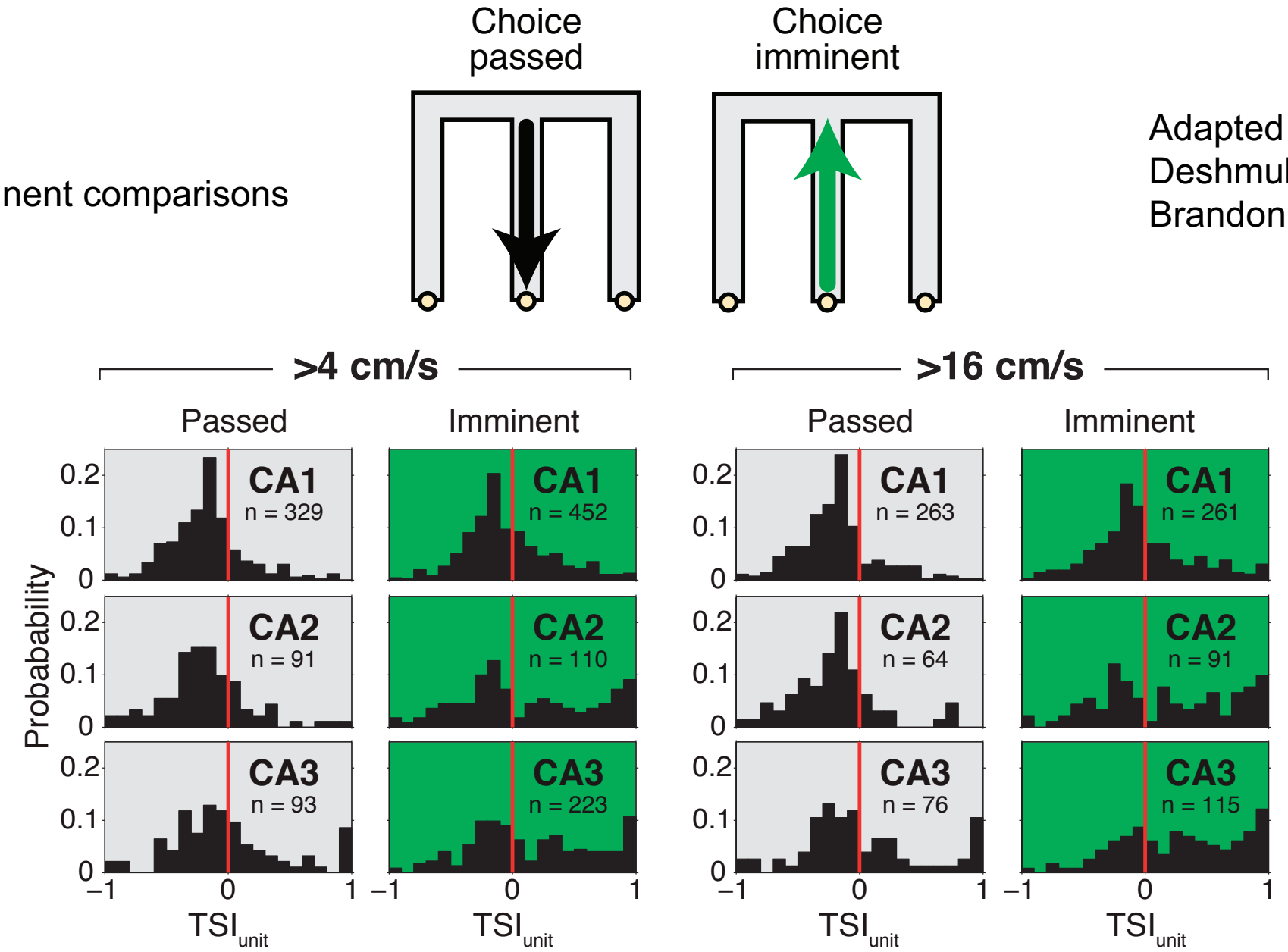
~8%

~16%

~9400 pairs total

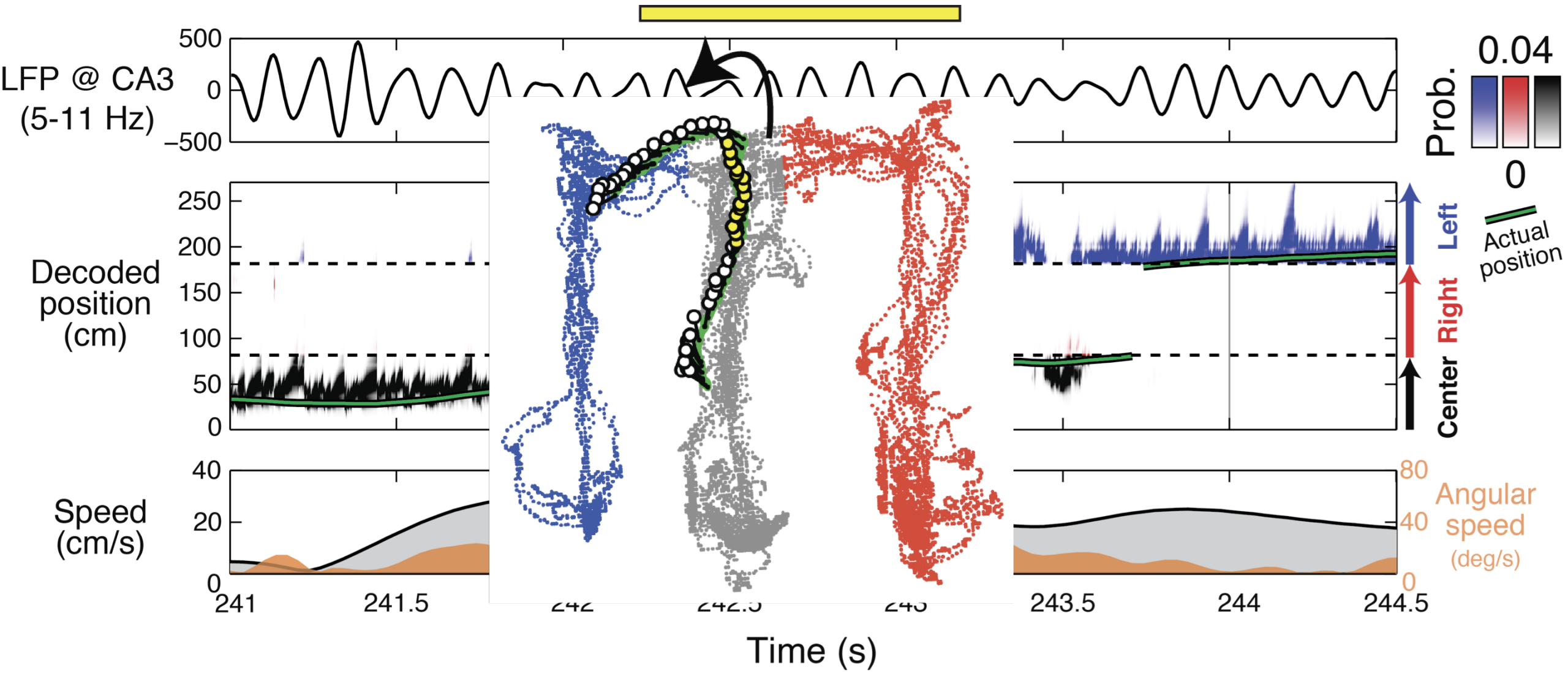
Prevalence in Single Units –Theta Skip Index

All passed vs. imminent comparisons
P < 0.01



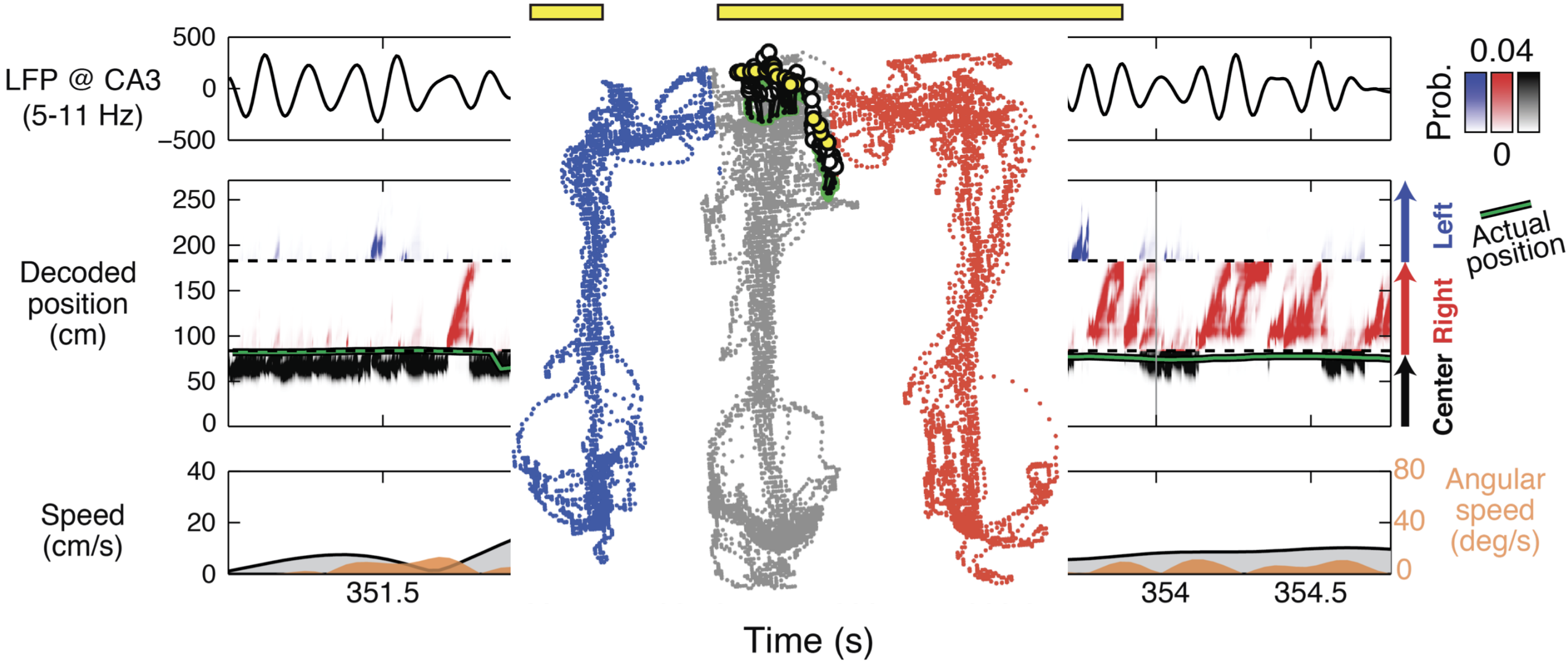
Adapted from:
Deshmukh et. al. (2010)
Brandon et. al. (2013)

Alternating Representations of Future Possibilities



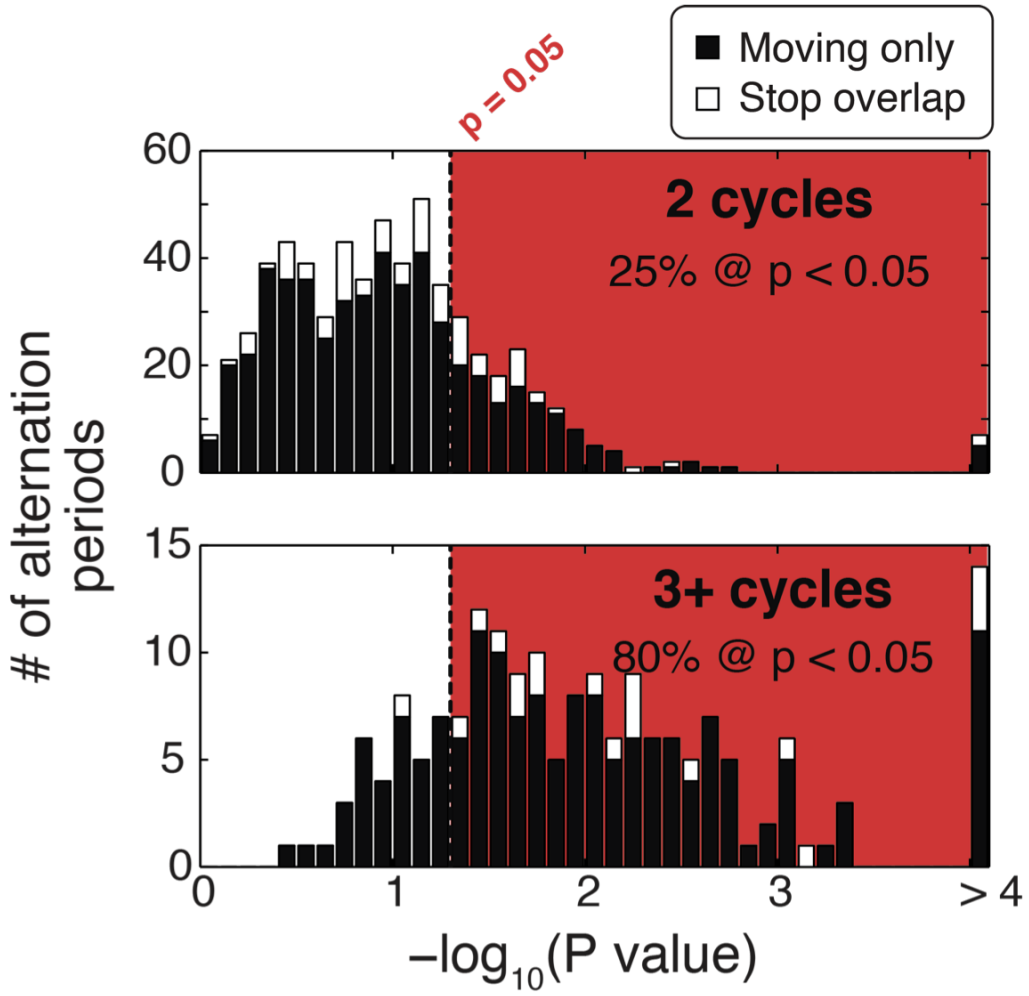
Clusterless decoding method:
Deng et. al. *Neural Computation (2015)*
See also Jezek et. al. *Nature* (2011)

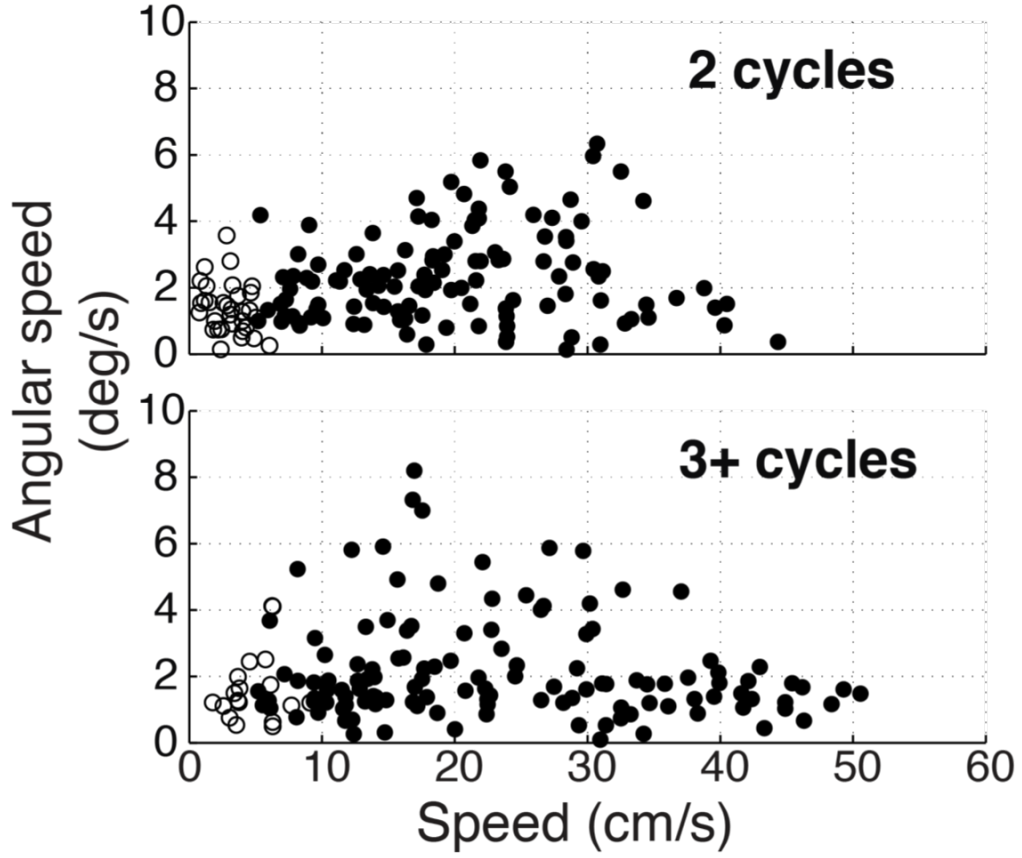
Alternating Representations of Future Possibilities



Clusterless decoding method:
Deng et. al. *Neural Computation (2015)*

Alternating Representations - Quantification



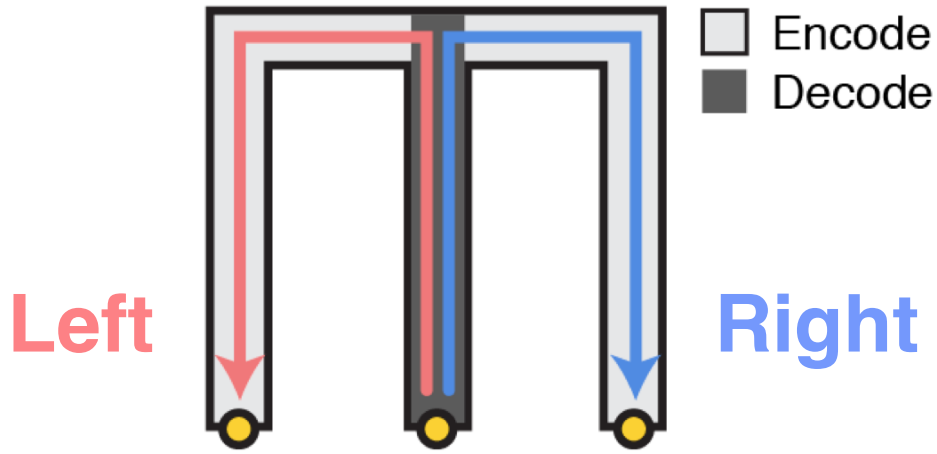


Spiking During Theta Sequences

- ☑ Time-compressed.
- ☑ Capable of representing future possibilities
- ☐ Related to behavioral decisions?

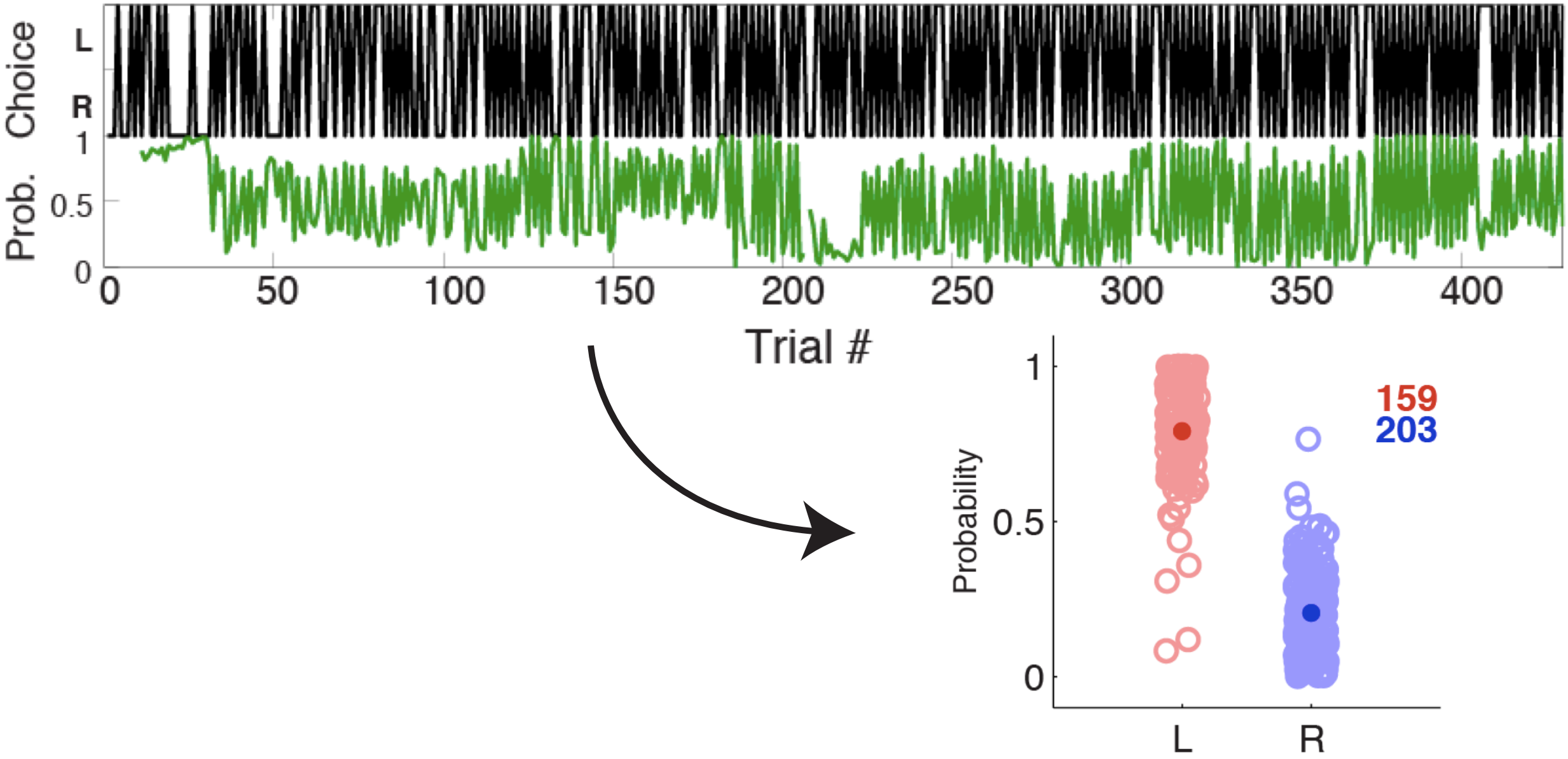
Relating Theta-timescale Activity to Behavior

Bayesian decoding of prospective (L vs. R) representation from place cells



Decode each theta cycle over entire time in middle arm (>2 s).

Theta-timescale Activity Predicts Upcoming Choices



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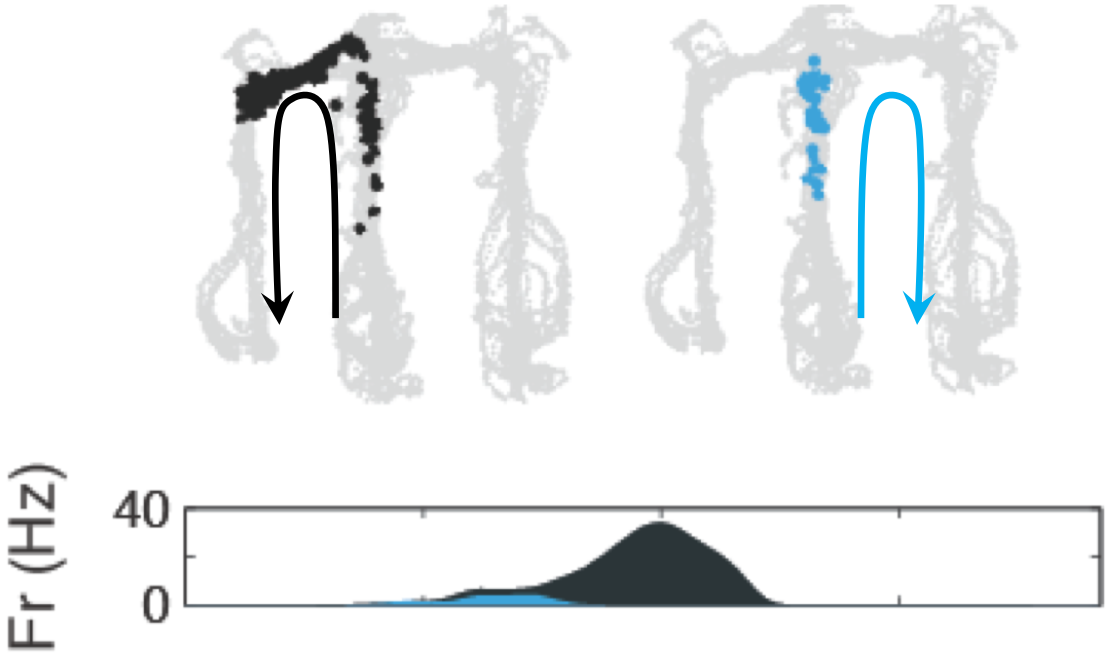
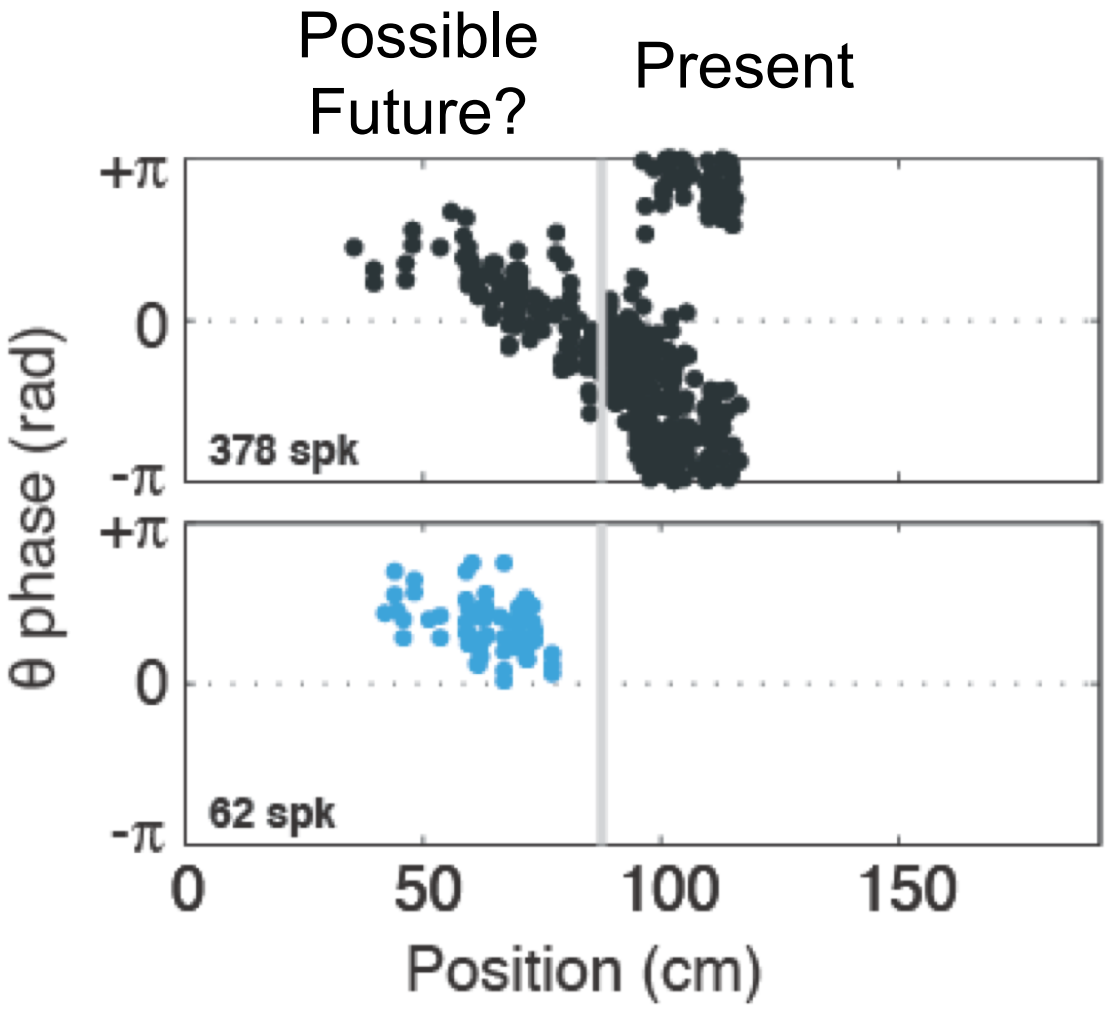
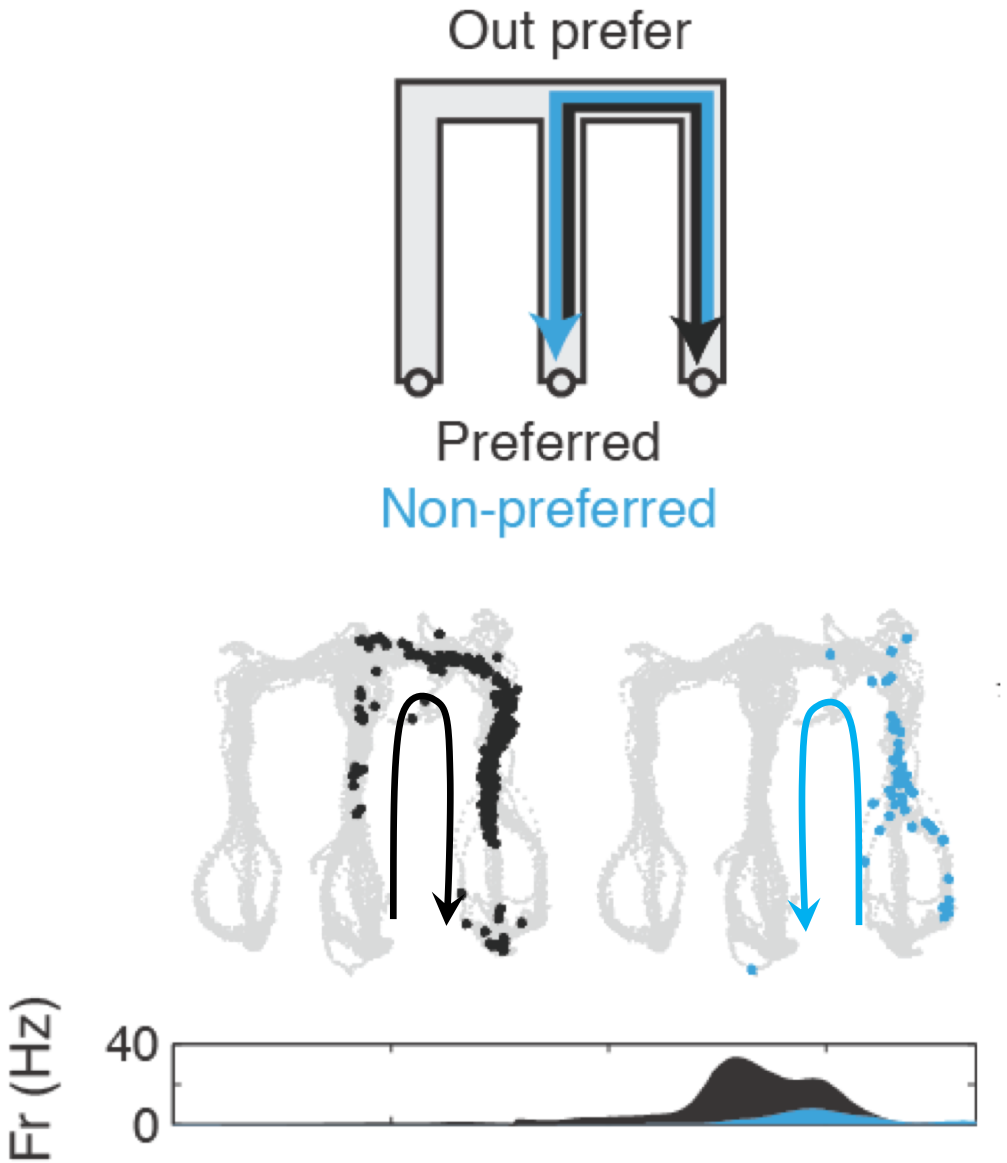
Current vs. Future Representations and Theta Phase

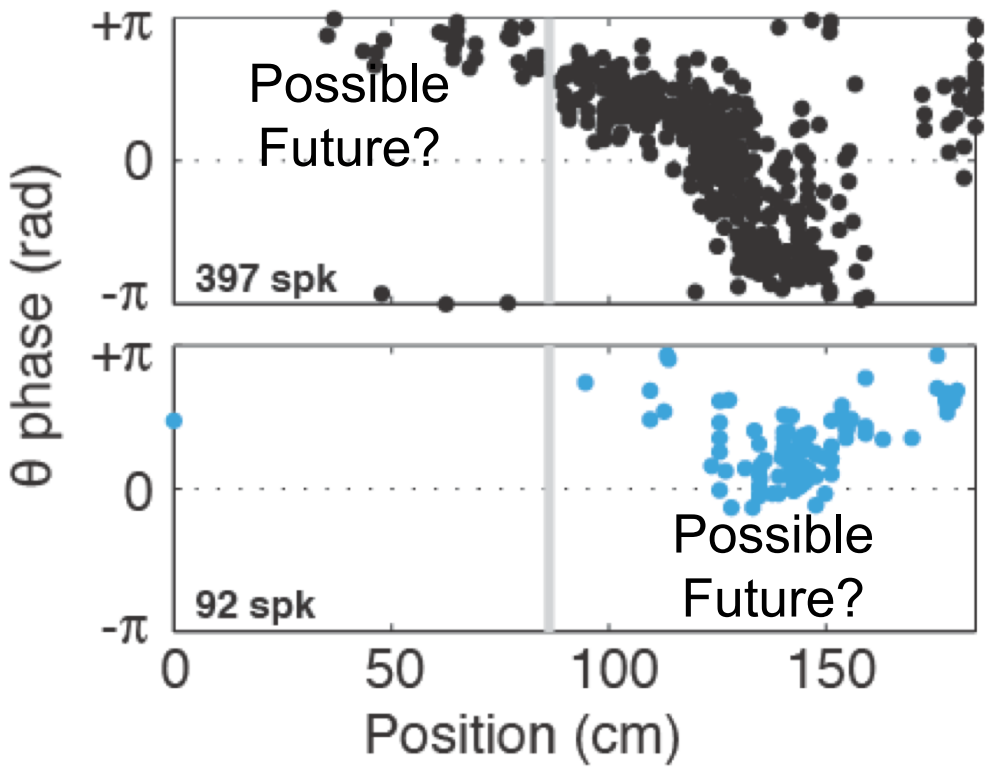


One unit, left and right trajectories

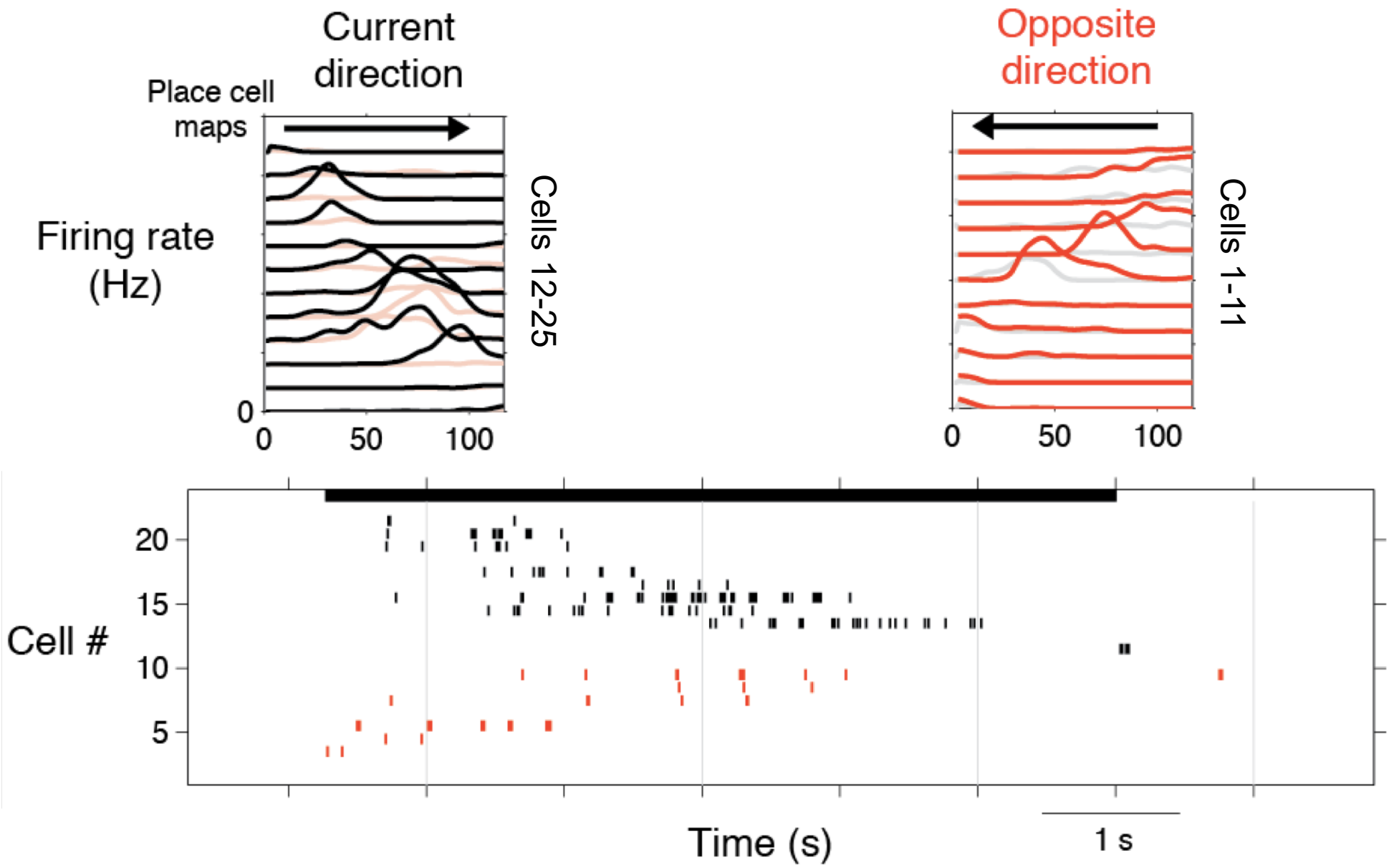


Preferred vs. Non-preferred Directional Representations

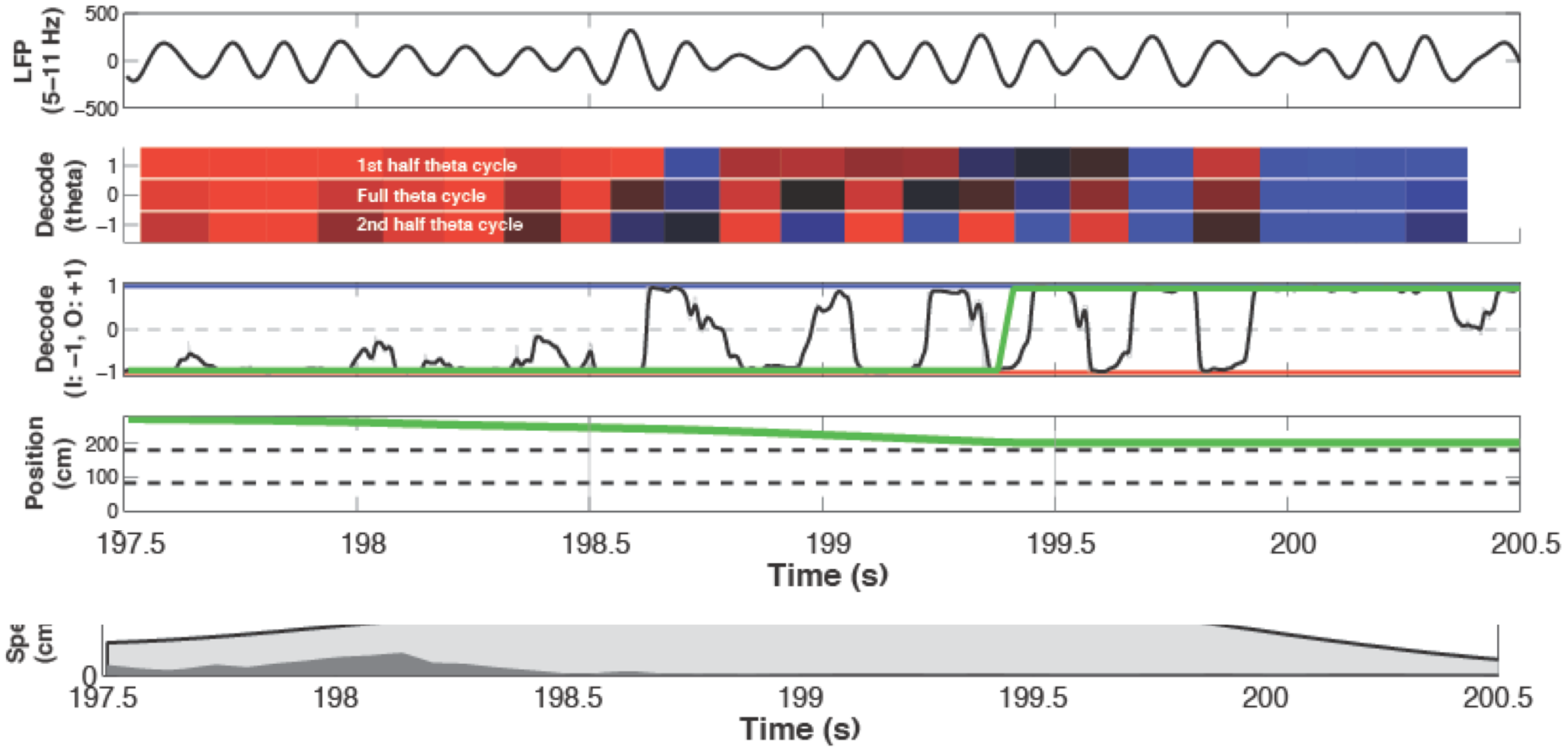




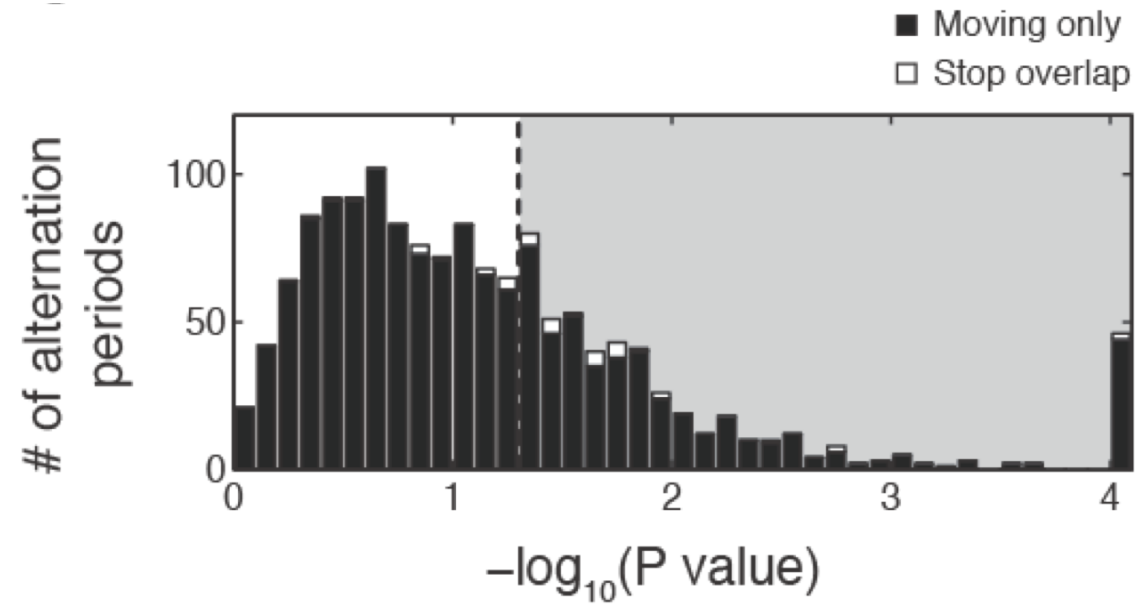
Ensemble Organization of Directional Representations

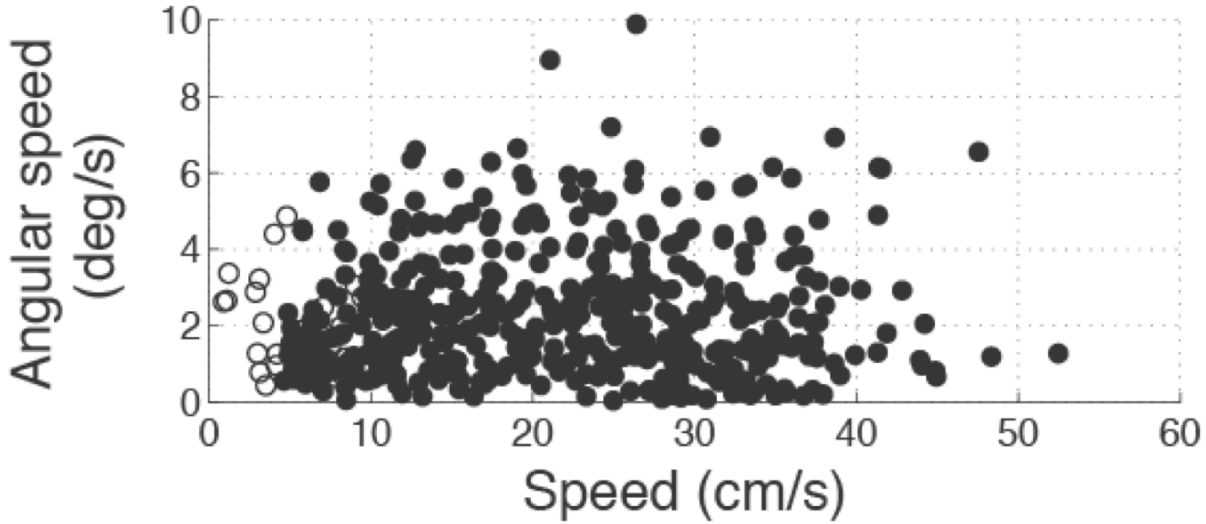


Theta-paced Alternation of Directional Representations



Ensemble Organization of Directional Representations





Conclusions

- We find frequent alternation between representations of future possibilities across theta cycles.
- This alternation is not limited to Vicarious Trial and Error (VTE) behaviors.
- Alternation occurs for both divergent paths and opposite directions of travel.
- Theta-paced alternation could inform upcoming decisions and/or reflect previous decisions.

Lab members and collaborators

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