

# 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

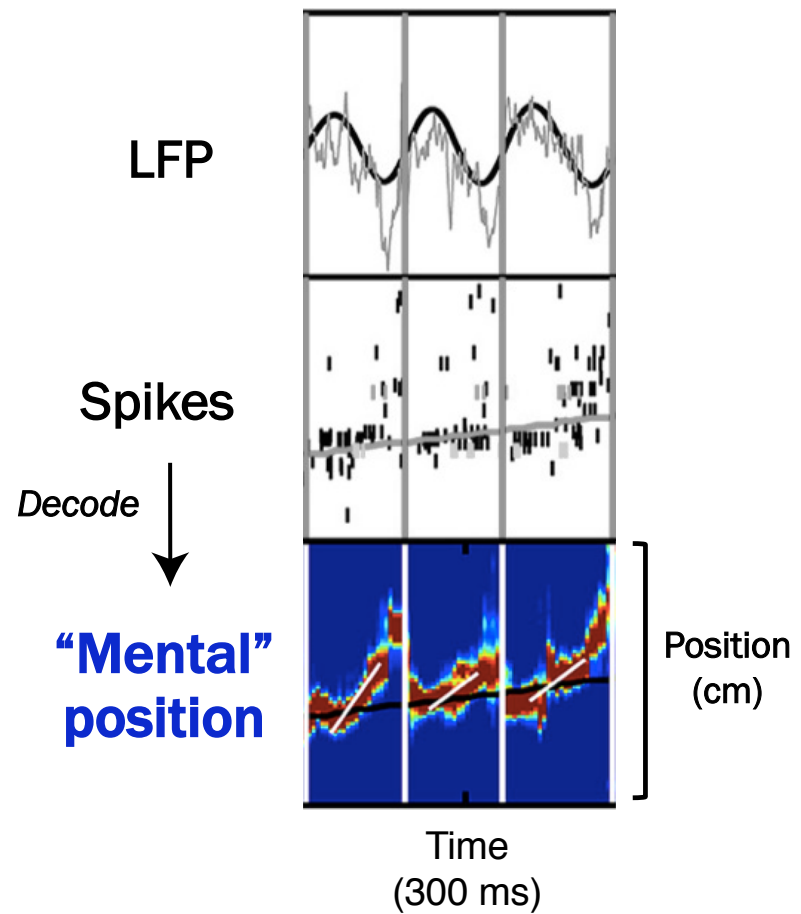
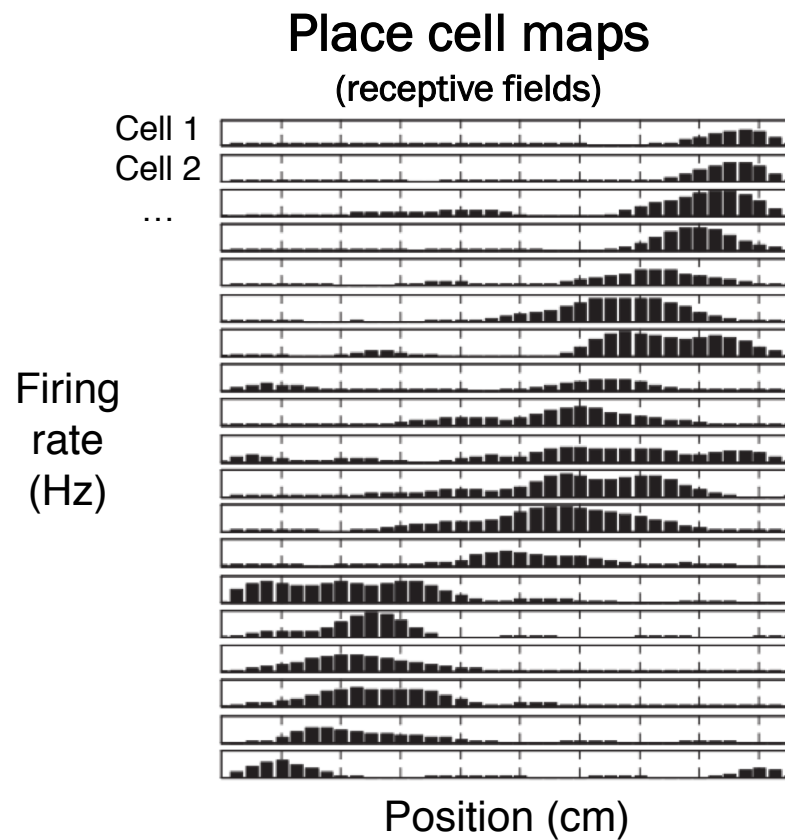


Figure from Feng & Foster (2015)



# Hippocampal Theta Sequences

= Population firing sequences that encode sequences in space

Each sequence lasts ~100 ms.

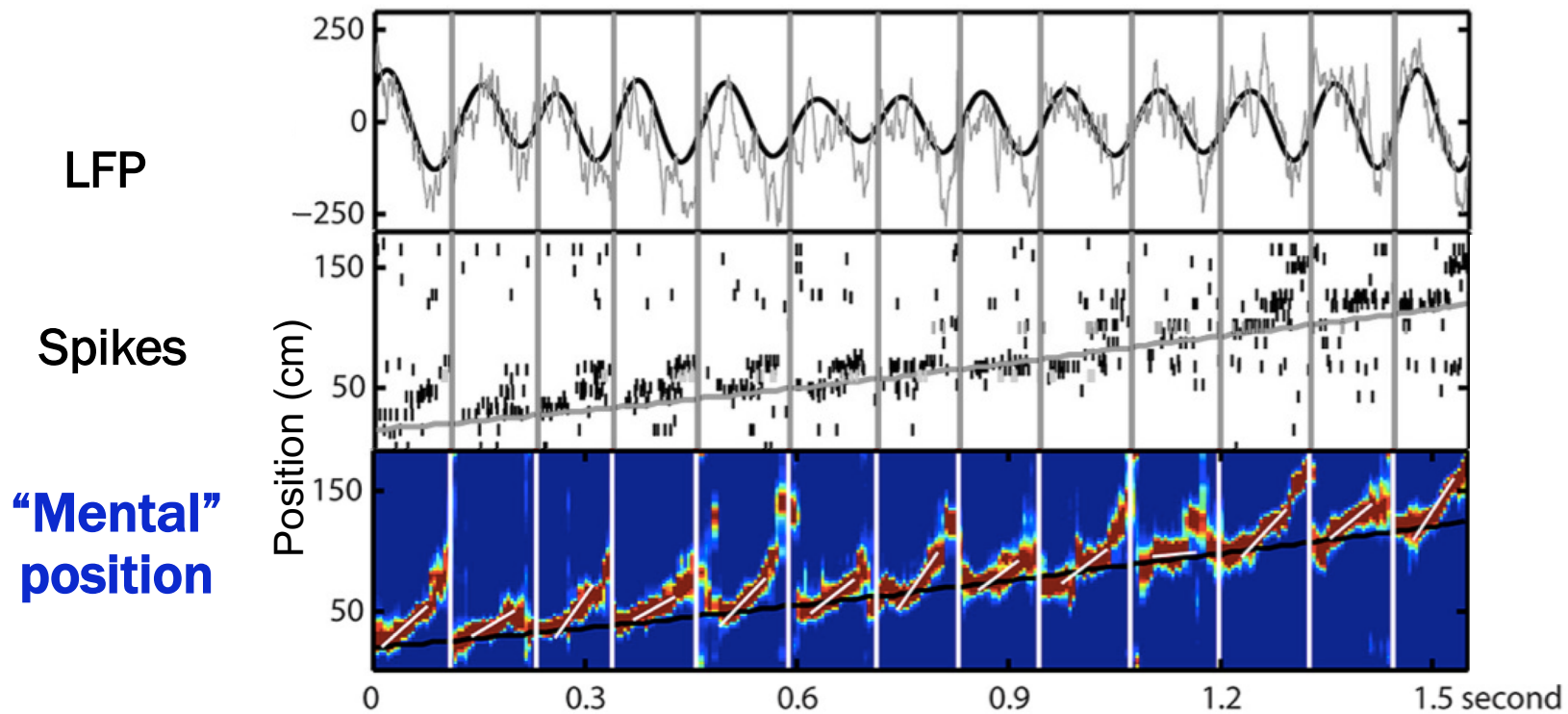
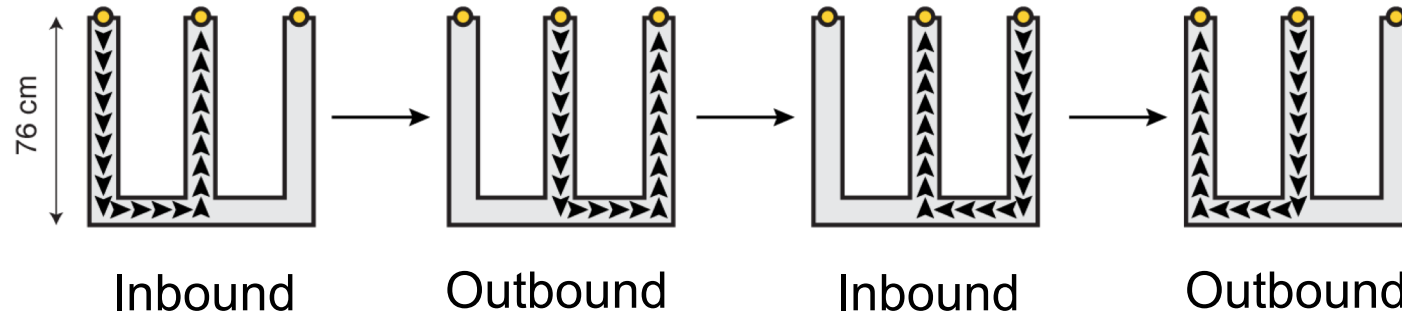


Figure from Feng & Foster (2015)

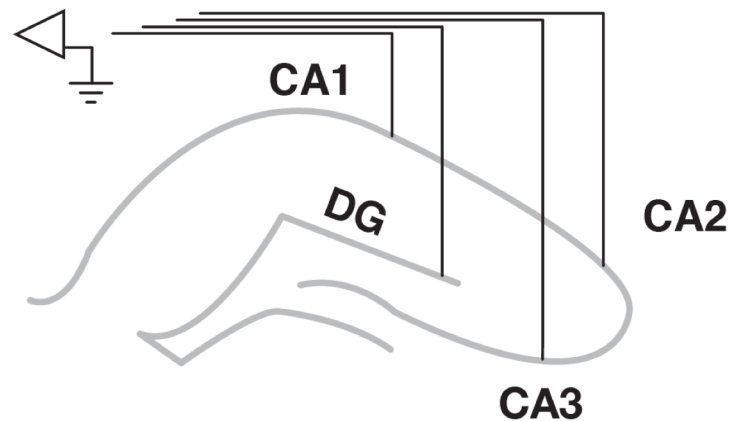
## Spiking During Hippocampal Theta Sequences

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

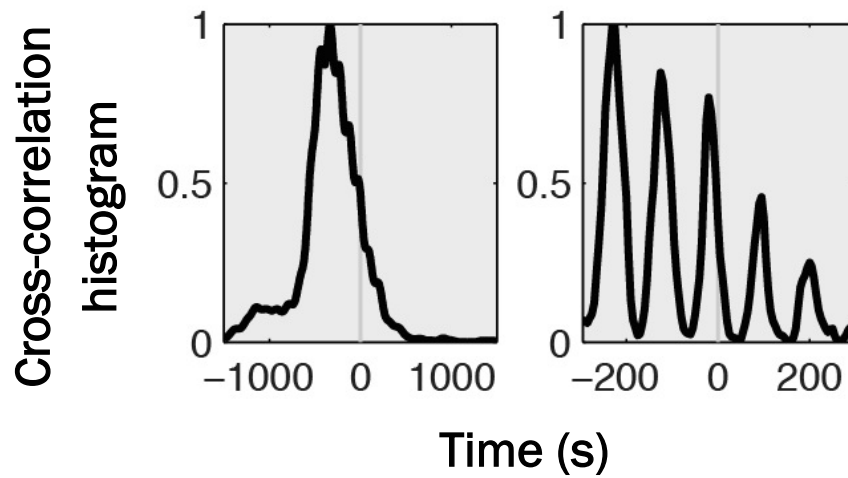
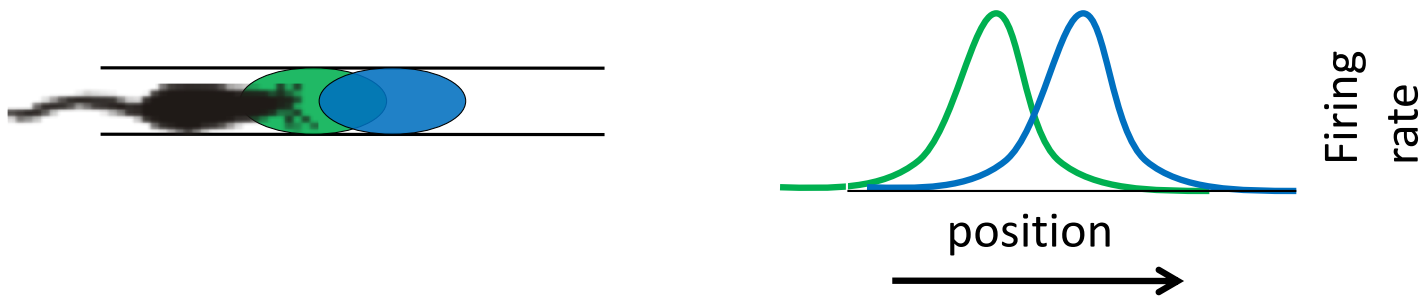
# Continuous Alternation Task and Regional Targeting



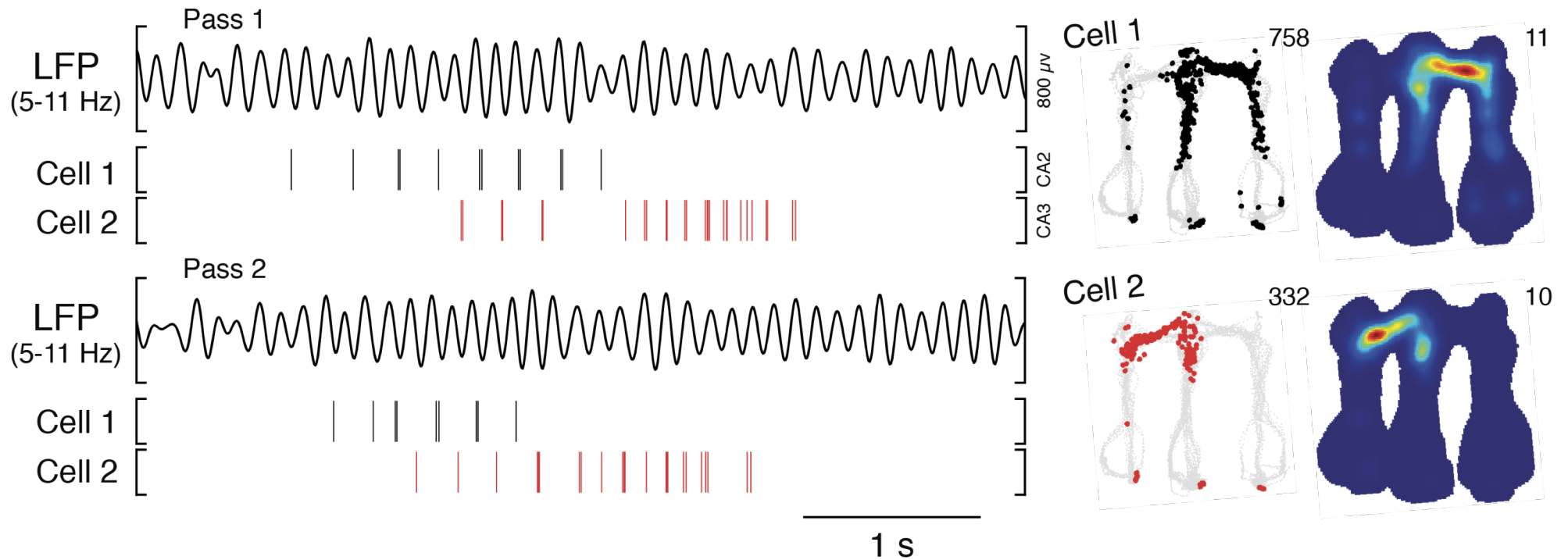
Outbound trials require memory of previous outbound choice



# Expected Co-firing Patterns

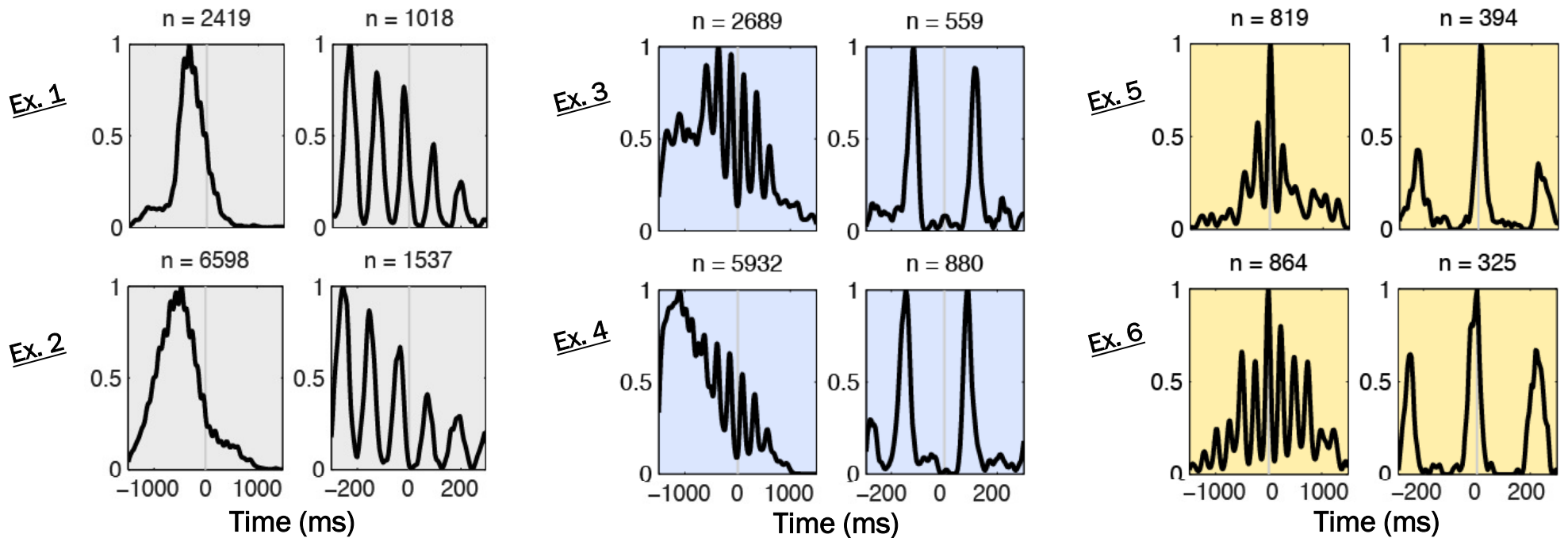


# Observed Co-firing Patterns (in a subset of pairs)



Example 1

# Normal, Anti-synchronous and Synchronous Pairs



~66%

~8%

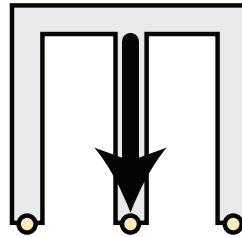
~16%

~9400 pairs total

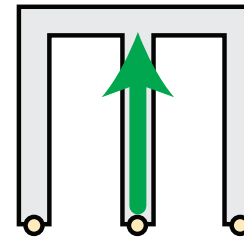
# Prevalence in Single Units –Theta Skip Index

All passed vs. imminent comparisons  
 $P < 0.01$

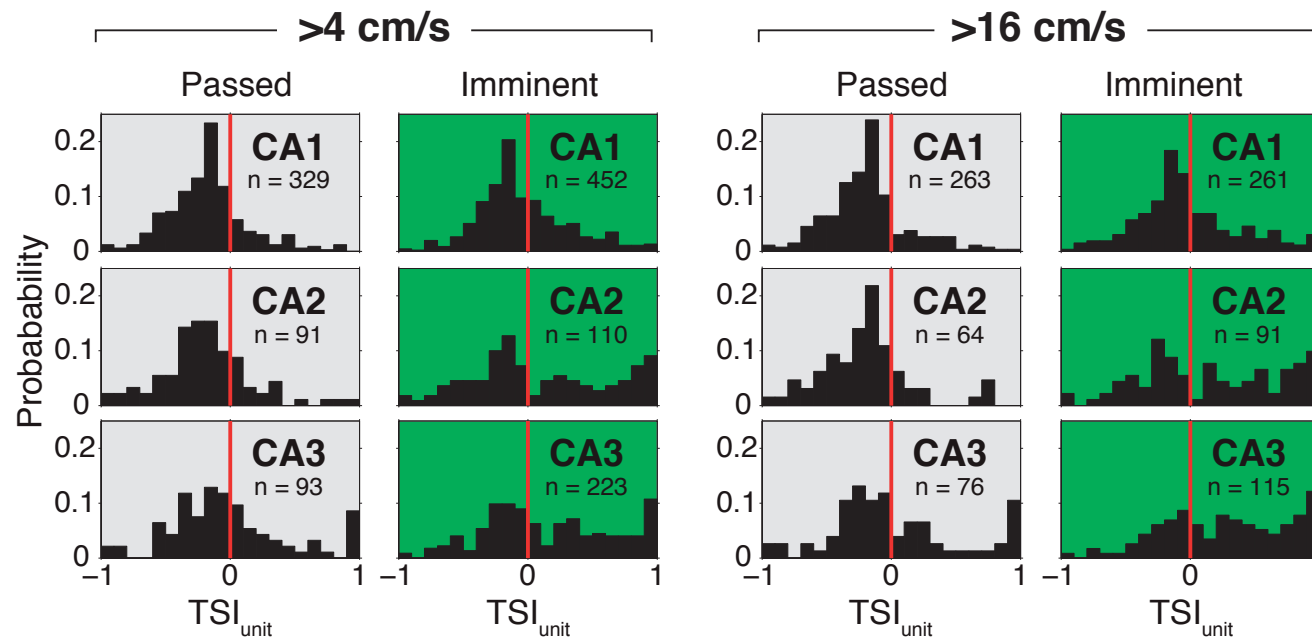
Choice  
passed



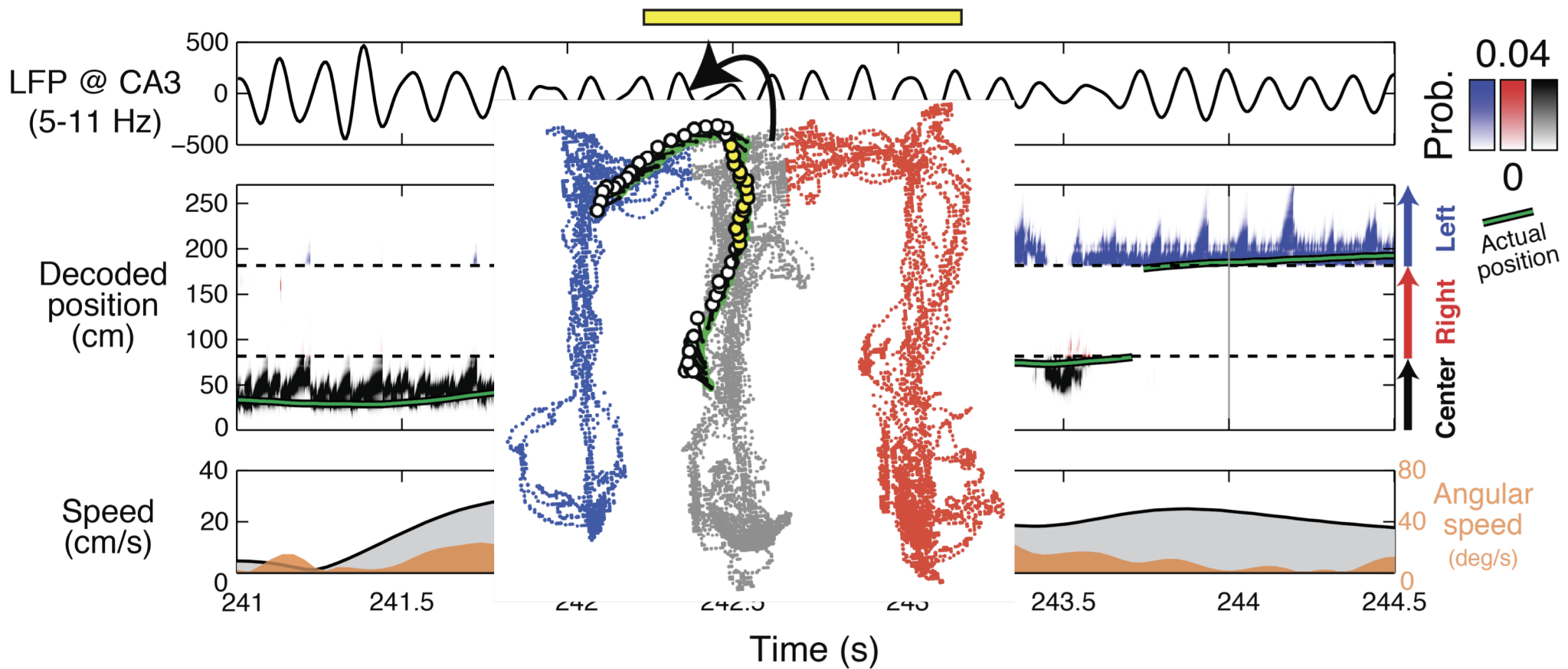
Choice  
imminent



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



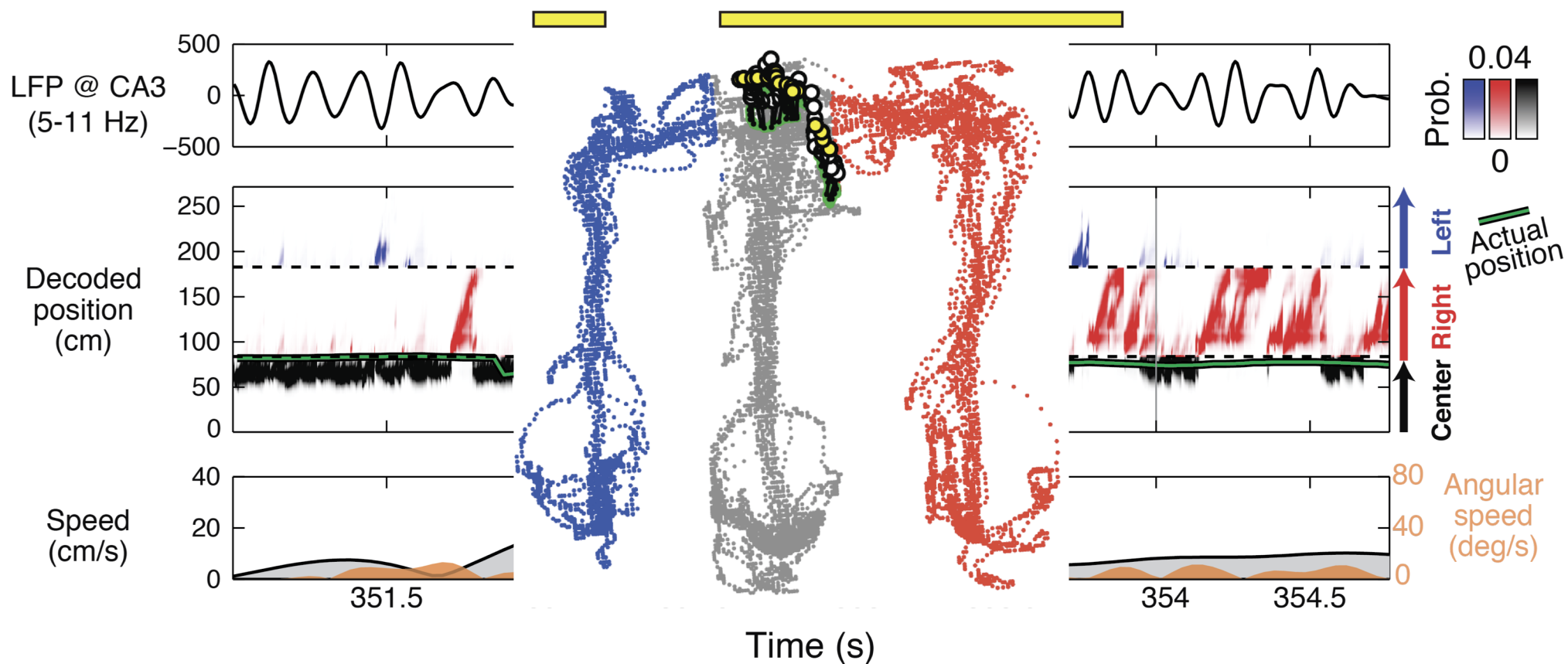
# Alternating Representations of Future Possibilities



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

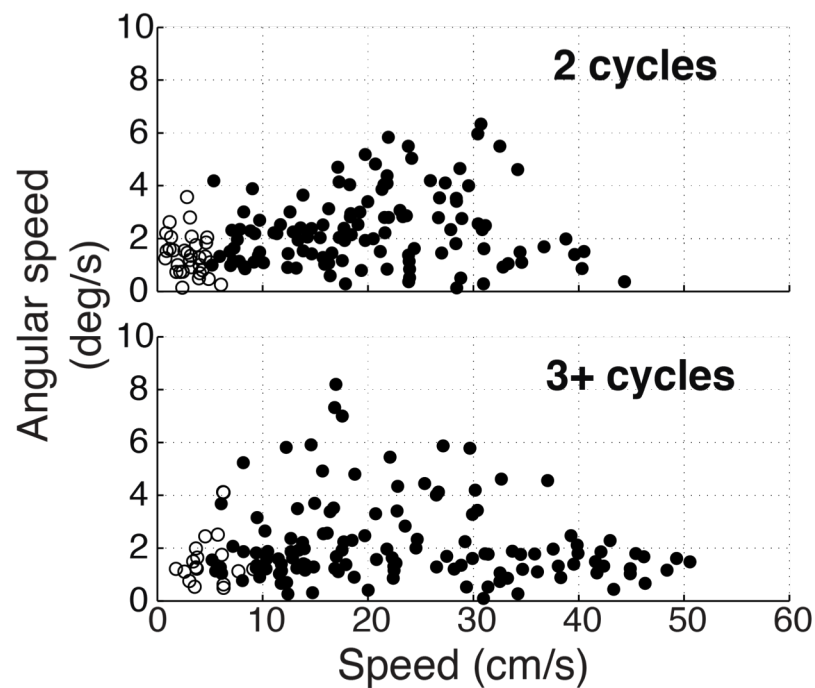
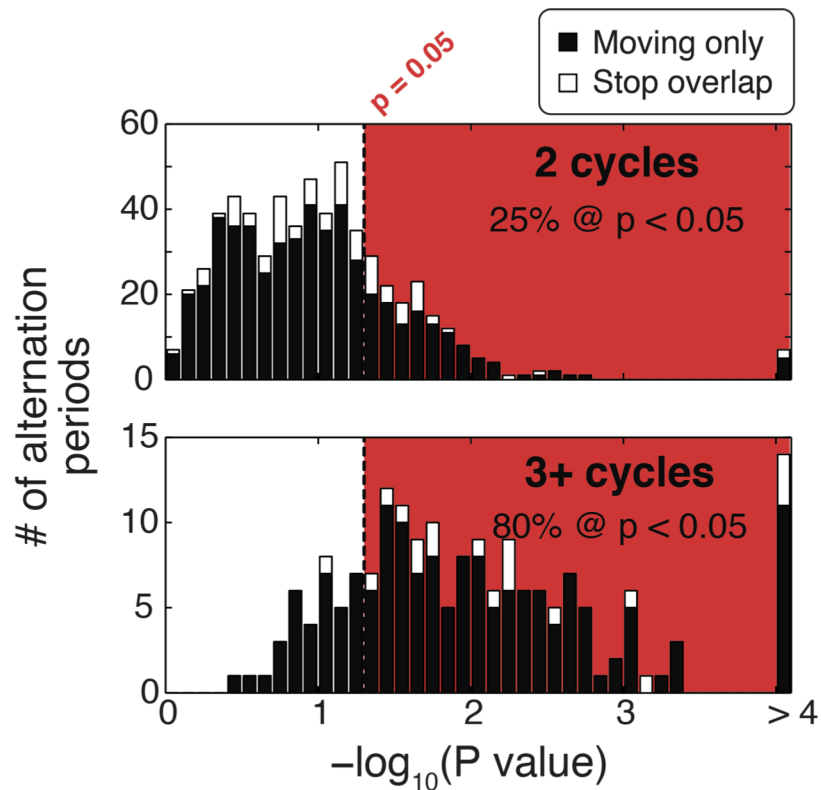


# Alternating Representations of Future Possibilities



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

# Alternating Representations - Quantification

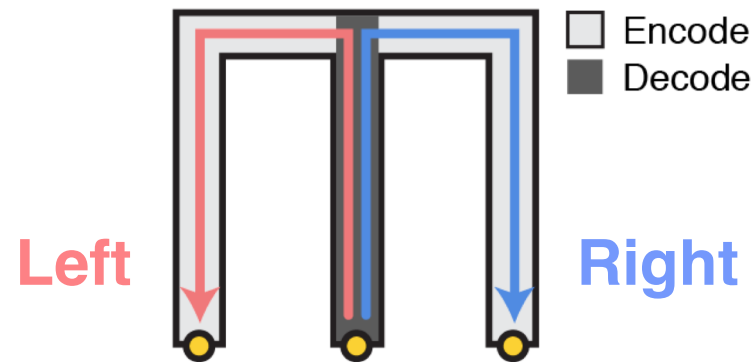


## Spiking During Theta Sequences

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

## Relating Theta-timescale Activity to Behavior

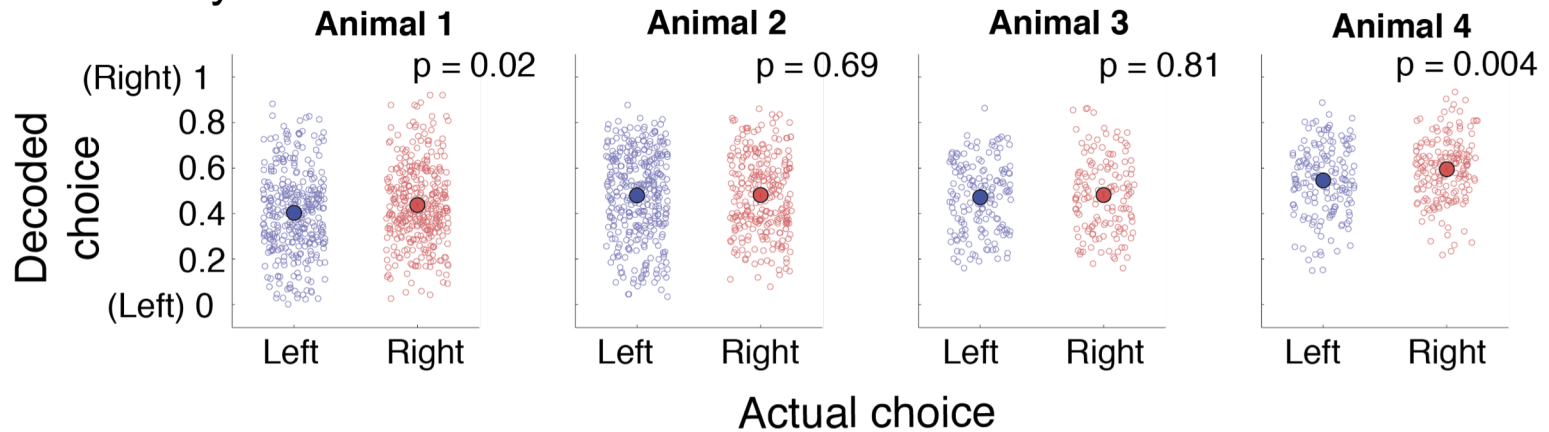
Bayesian decoding of prospective (L vs. R)  
representation from place cells



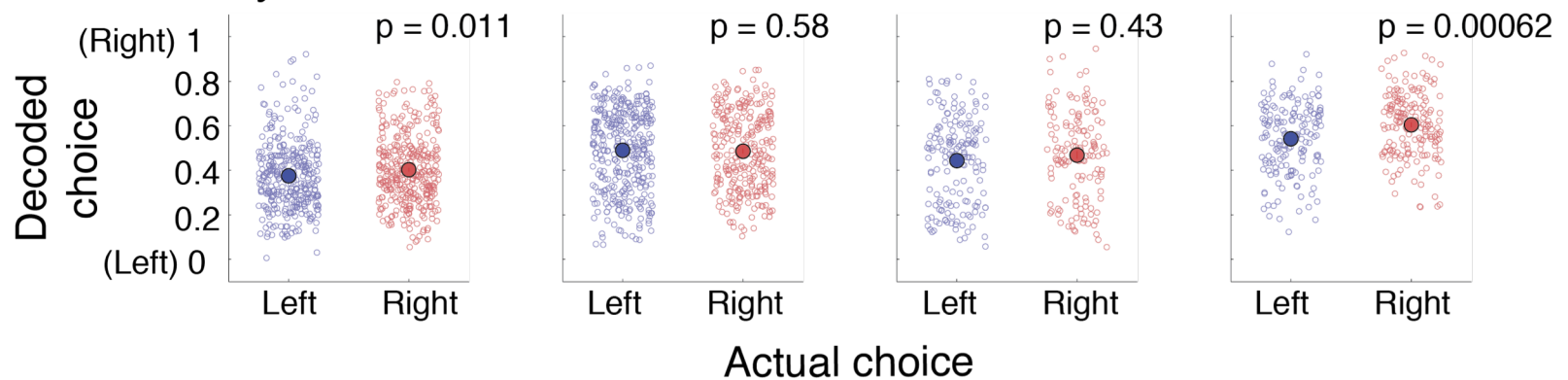
Decode each theta cycle over entire time  
in middle arm (>2 s).

# Weak Relationship between Activity and Upcoming Choices

First half theta cycle



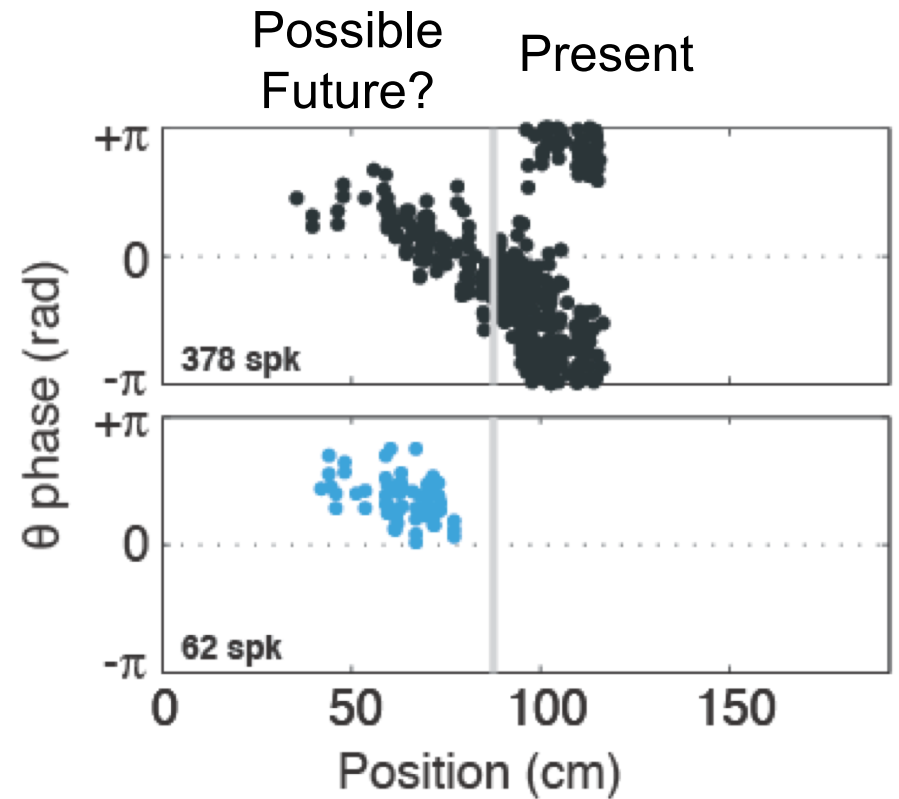
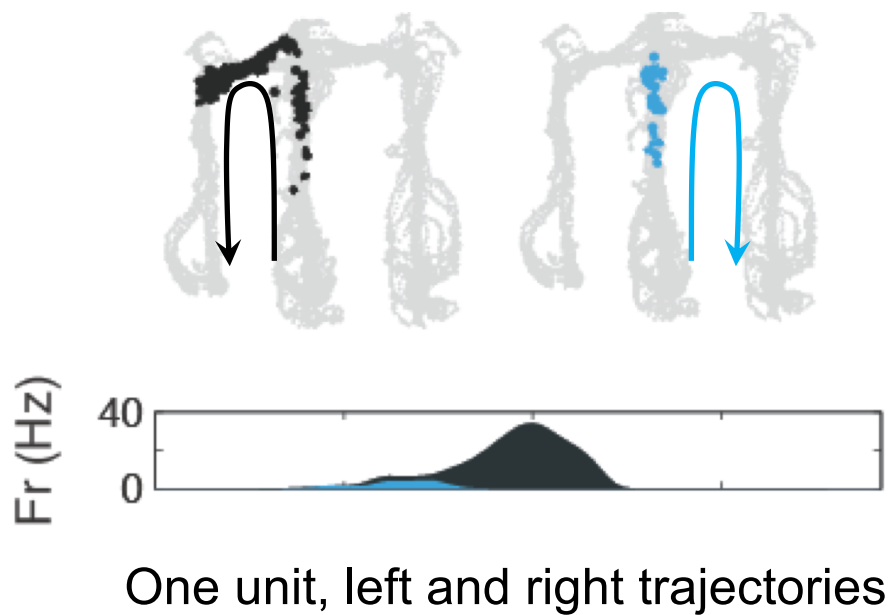
Second half theta cycle



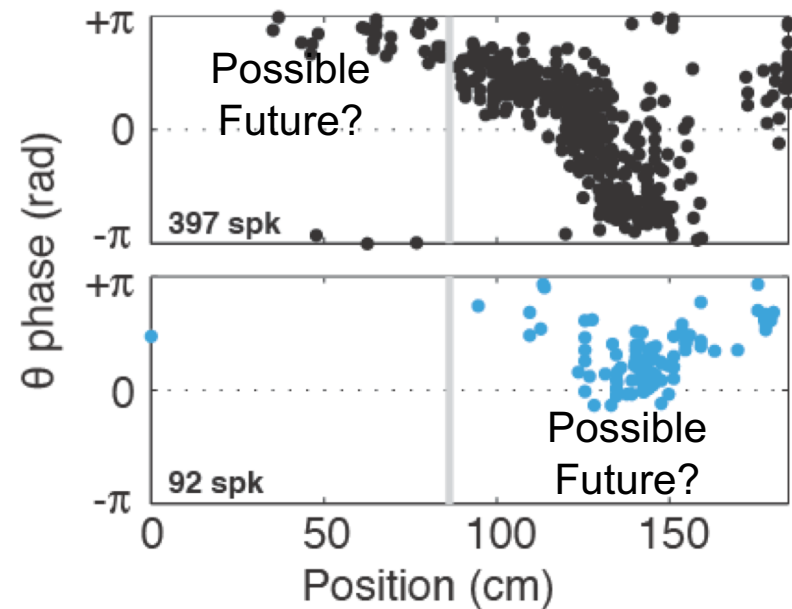
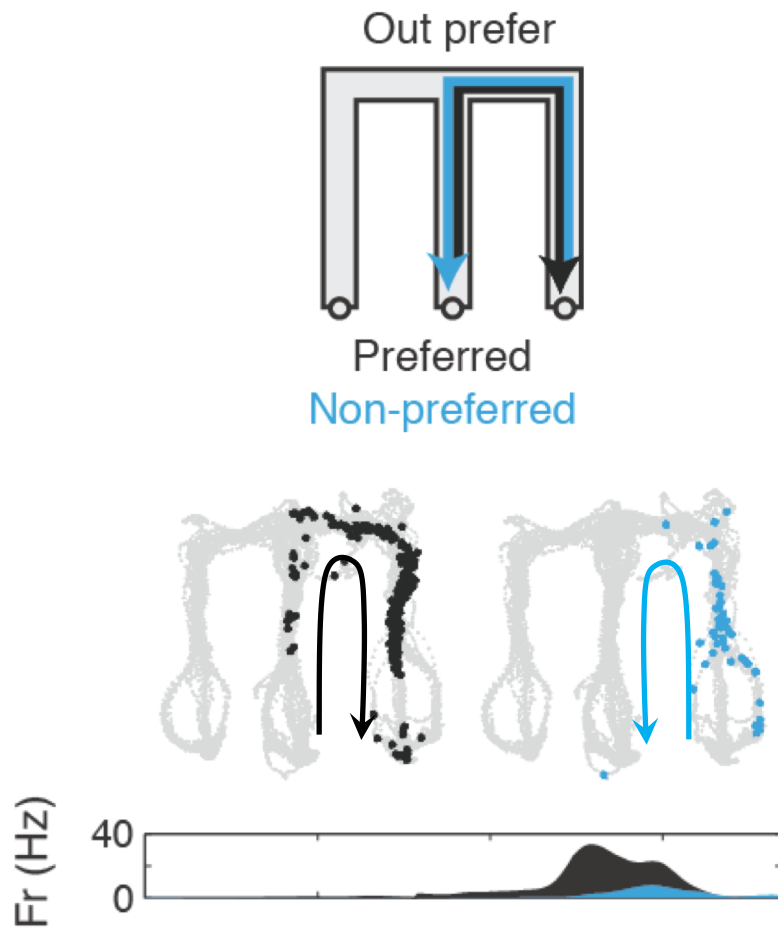
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# Current vs. Future Representations and Theta Phase

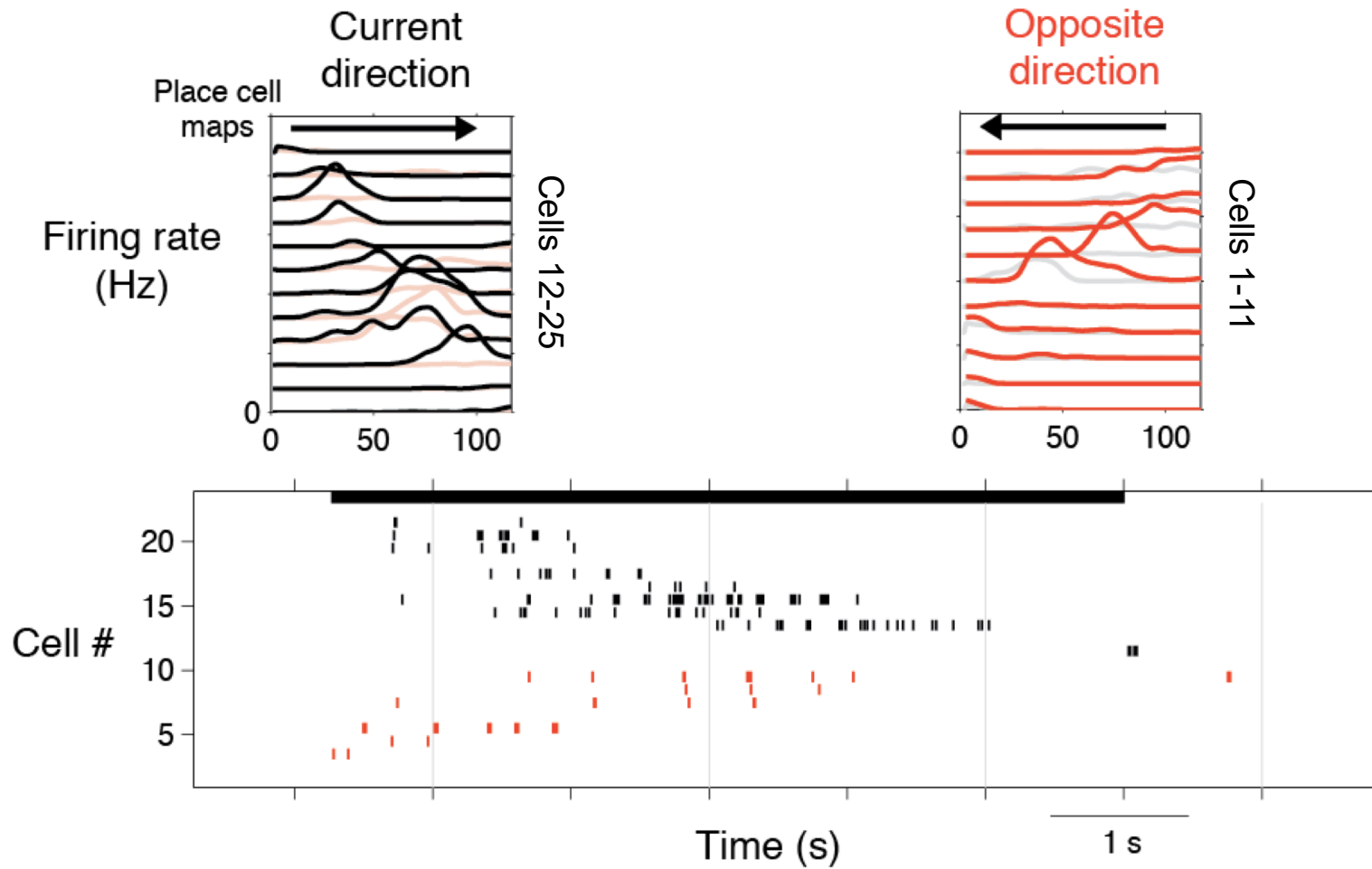


# Preferred vs. Non-preferred Directional Representations

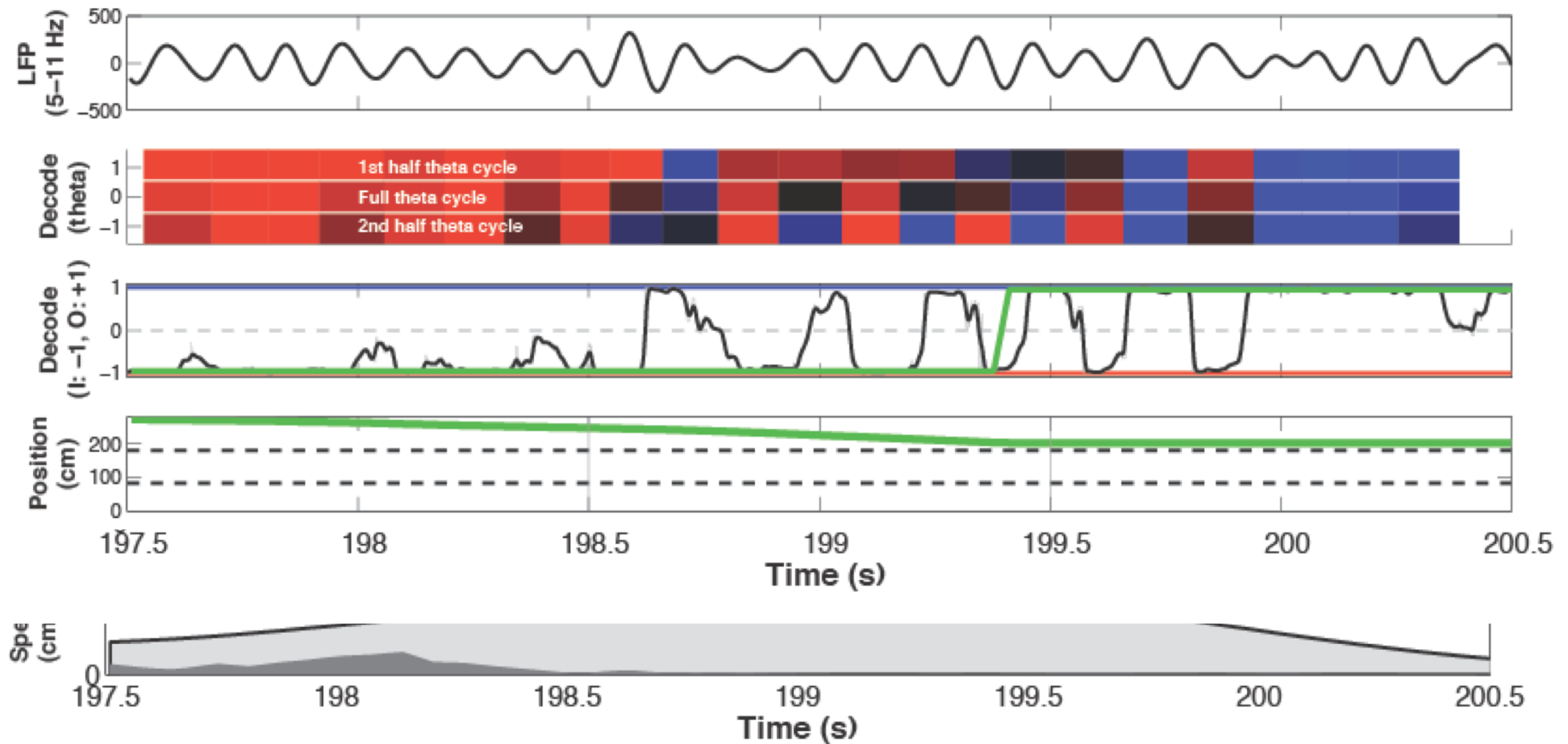




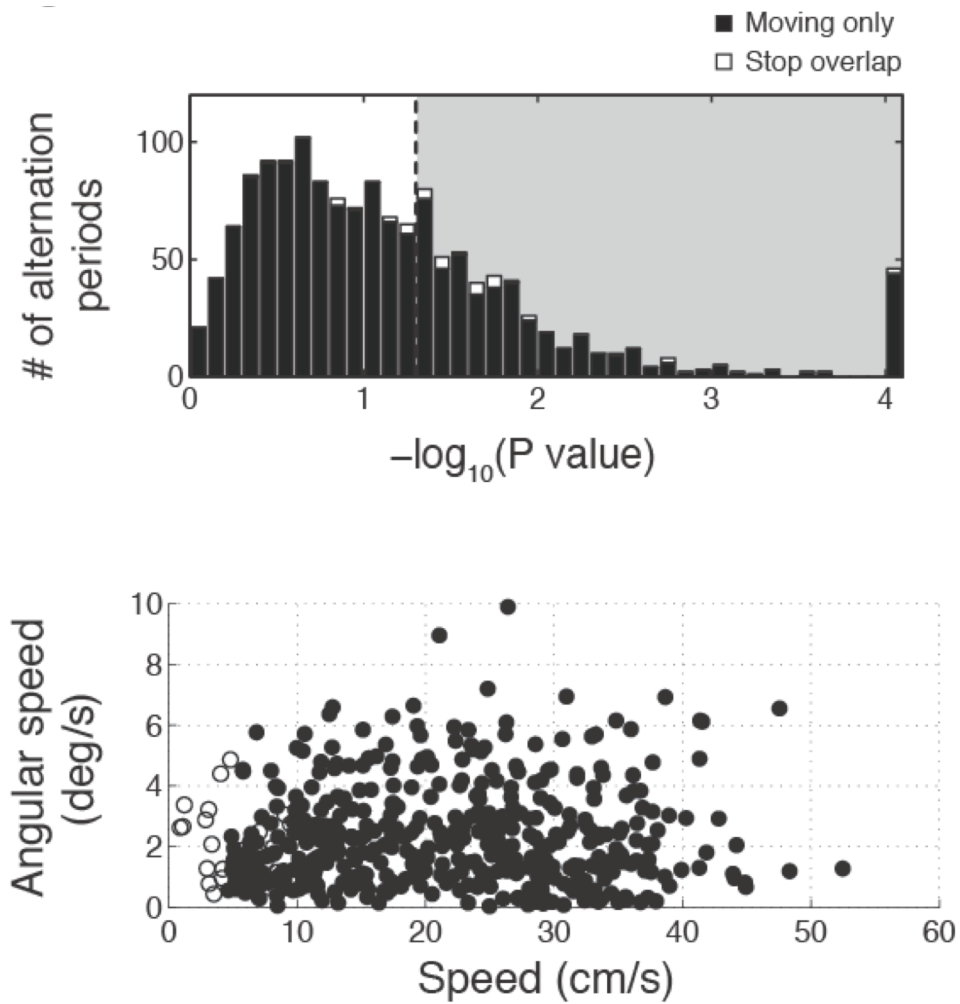
# Ensemble Organization of Directional Representations



# 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

## Lab Members

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**Funding:** HHMI, Simons Foundation, NIH, UCOP