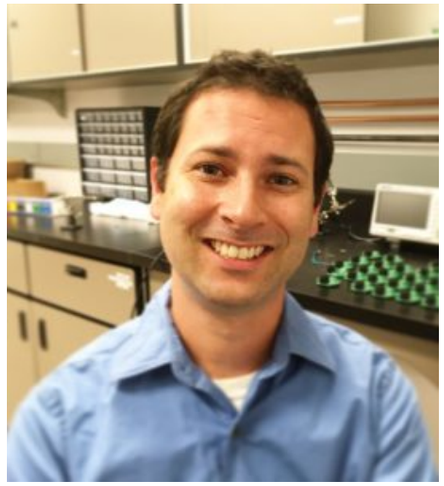
Dynamic, distributed decision-making by frontostriatal circuits

Rishidev Chaudhuri

CRCNS PI Meeting,
UC San Diego
November 13th 2025



CRCNS collaboration with Tim Hanks

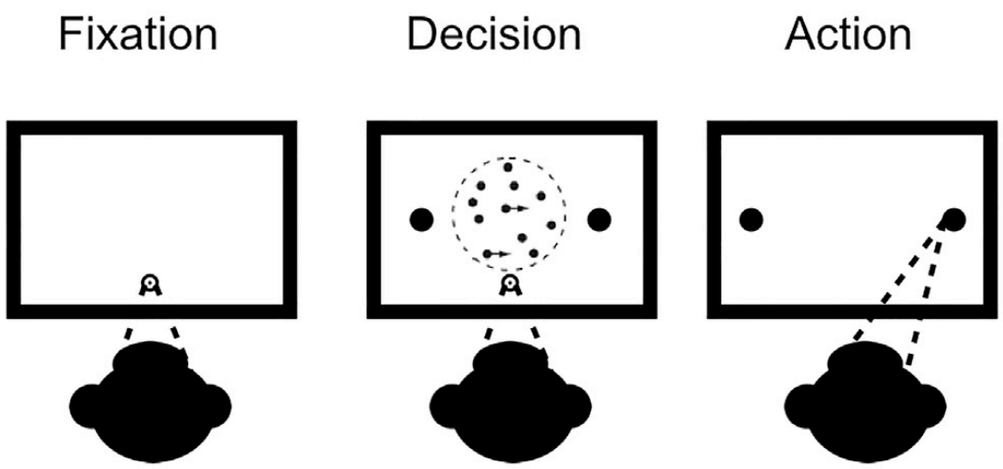
Goldring AB, et al., bioRxiv, 2025.11.07.687310; doi: 10.1101/2025.11.07.687310

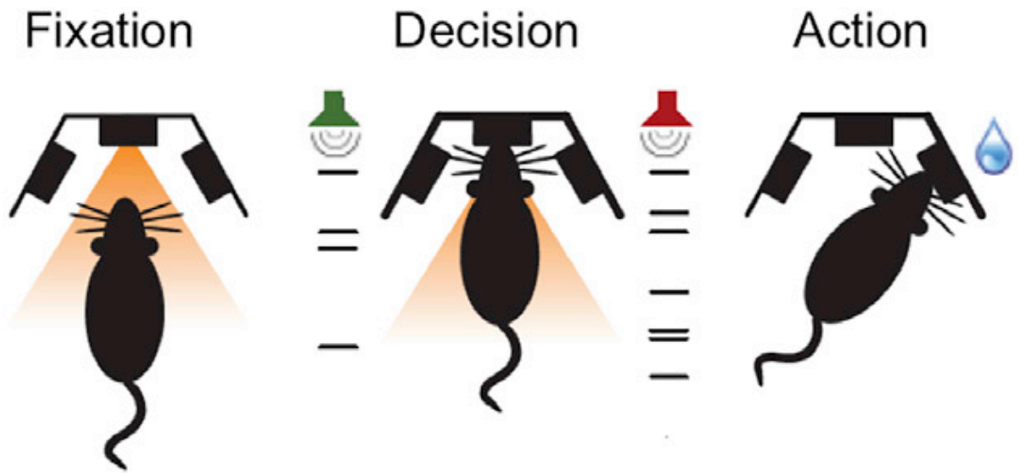
Nov. 16, 2025, 8:00 AM - 12:00 PM, PSTR088.12 - From impulsivity to engagement: latent behavioral states modulate neural dynamics in perceptual decision-making

Nov. 16, 2025, 8:00 AM - 12:00 PM PSTR088.12 - From impulsivity to engagement: latent behavioral states modulate neural dynamics in perceptual decision-making

UCDAVIS
Center for Neuroscience

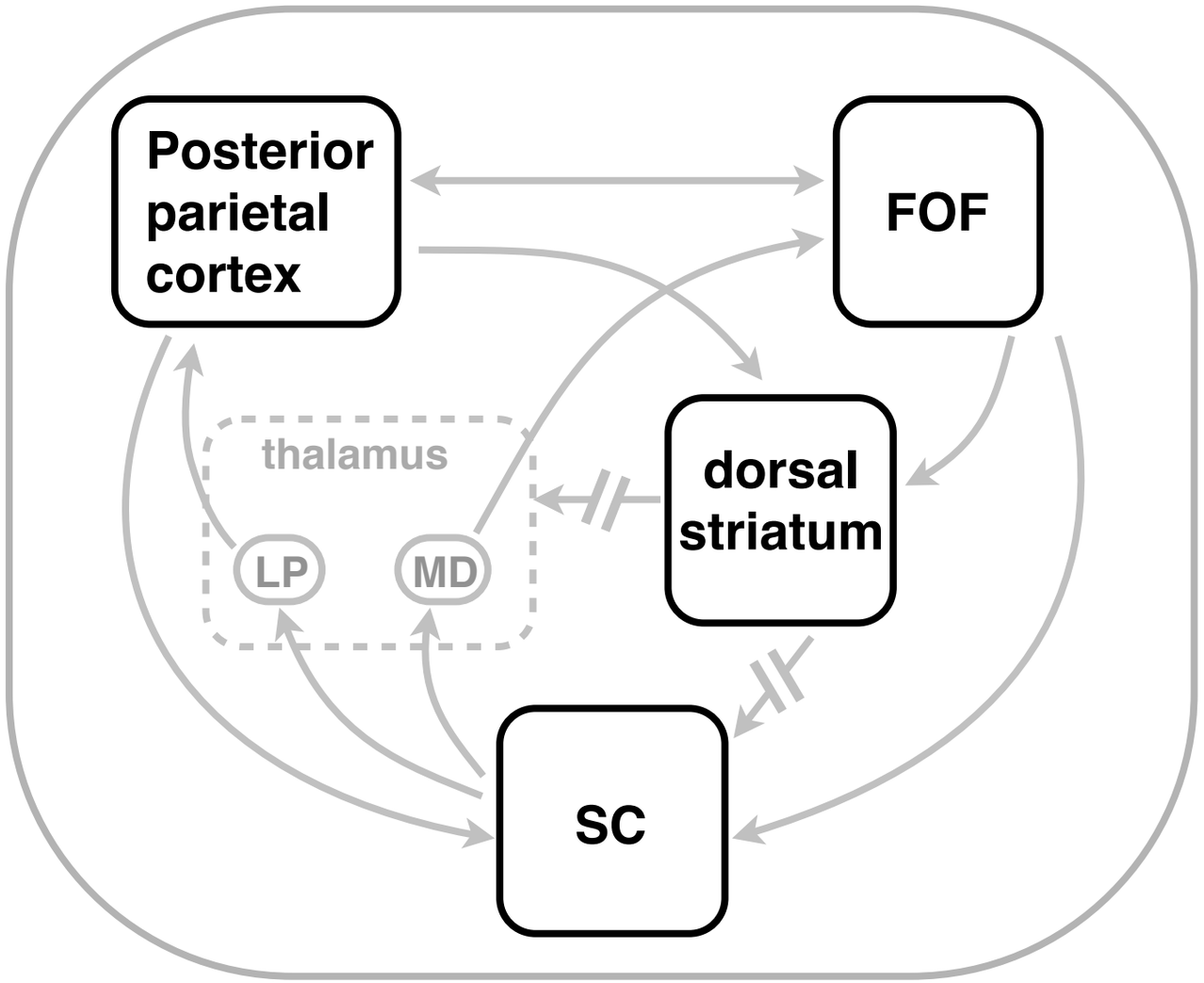
Perceptual decision-making tasks: convert noisy sensory signals to a motor act





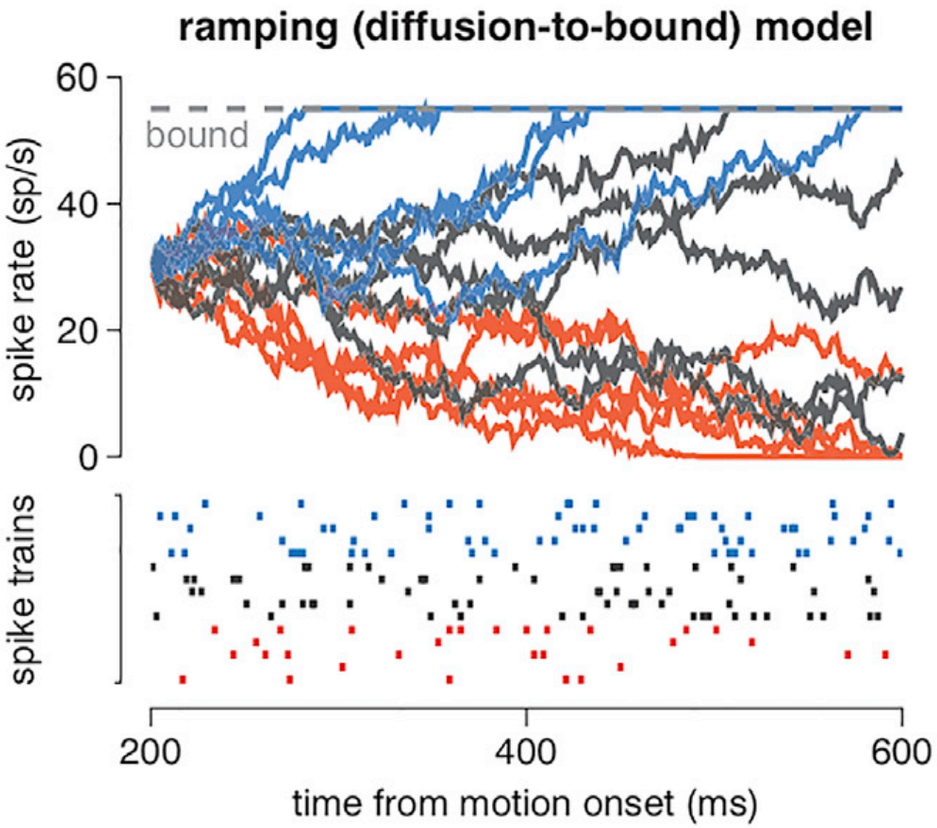
Hanks & Summerfield, 2017

Perceptual decision-making relies on a distributed network of cortical and subcortical areas

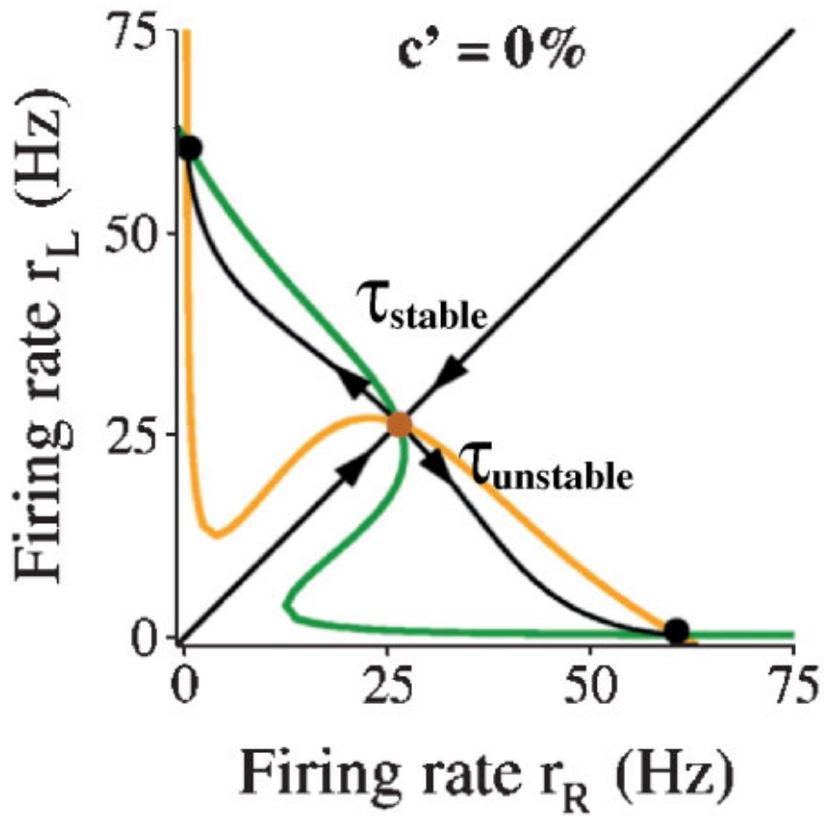


Evolutionarily conserved across primates & rodents

Rich paradigm for understanding how neural dynamics subserve cognition



Hanks & Summerfield, 2017

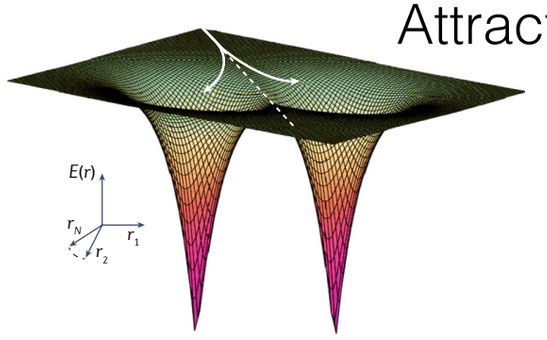


Wong et al., 2007

Basic questions about this distributed network

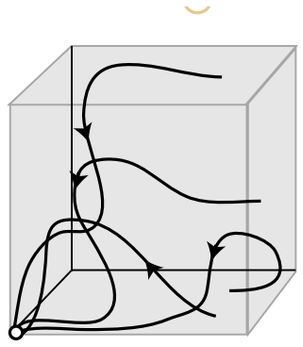
- What dynamical regime is the network operating in?

Attractors



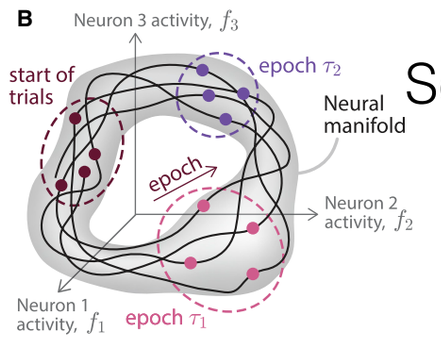
Khona & Fiete, 2022

Stimulus-driven transients



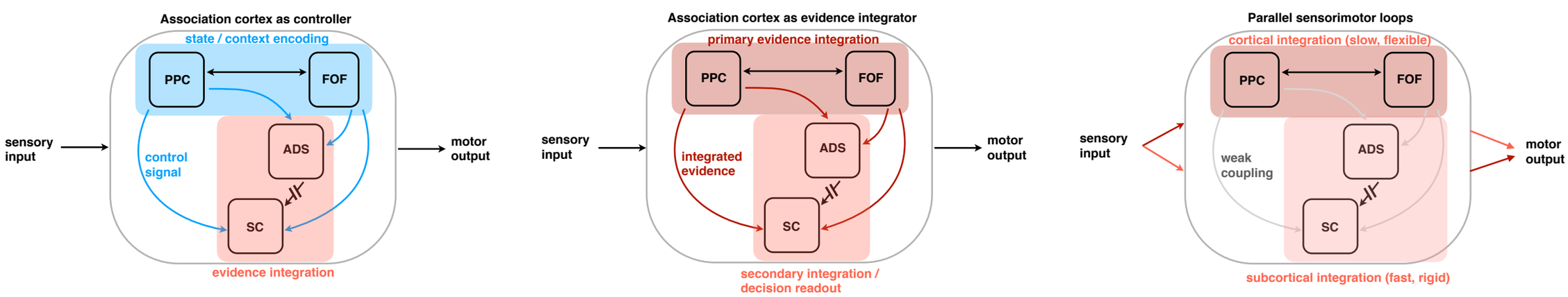
Chaudhuri & Fiete, 2016

Sequences

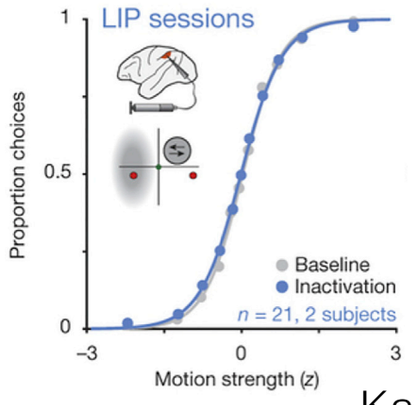


Koay et al., 2022

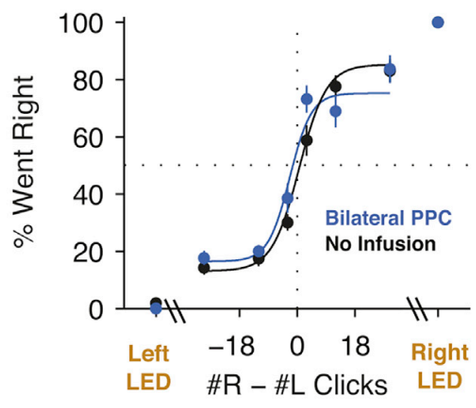
- What are the differential roles of cortical and subcortical areas?



- How do these networks reconfigure across conditions and perturbations?

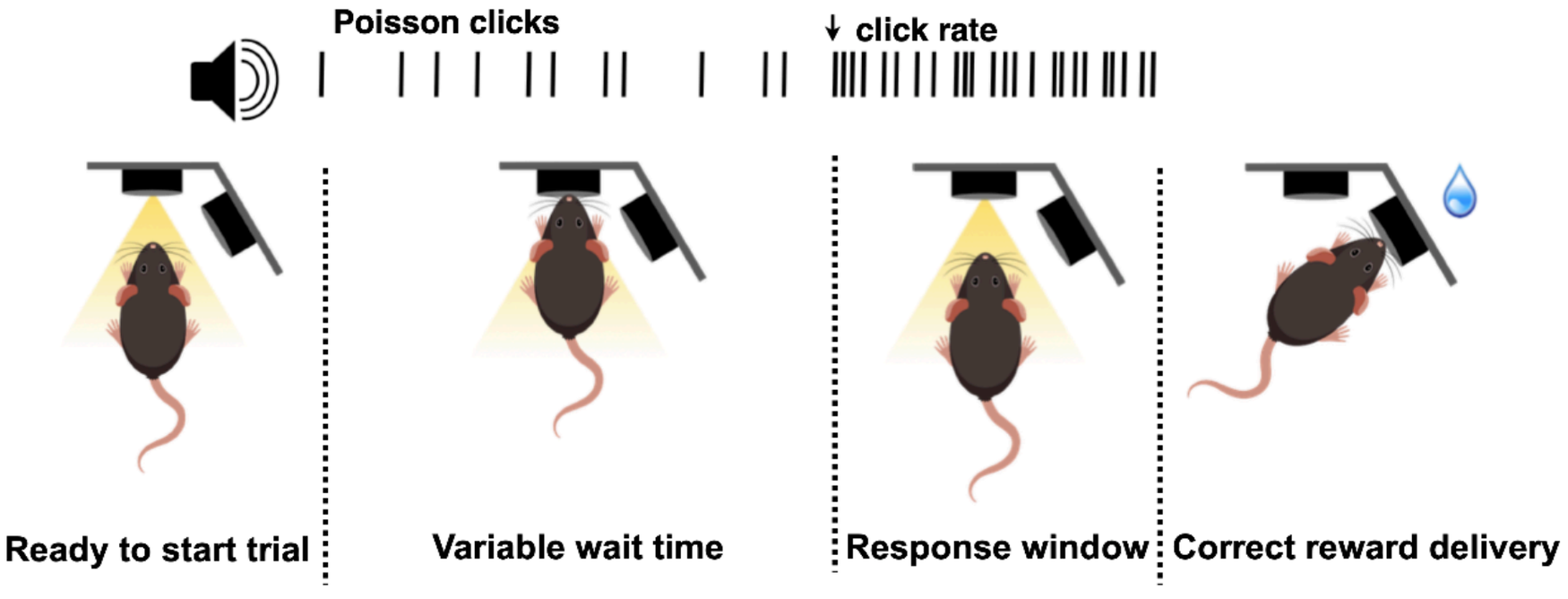


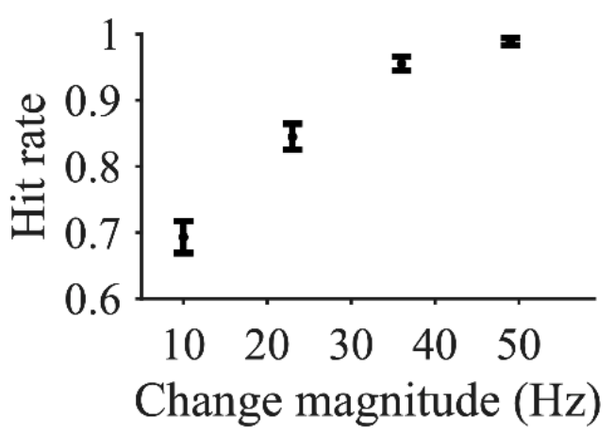
Katz et al., 2016

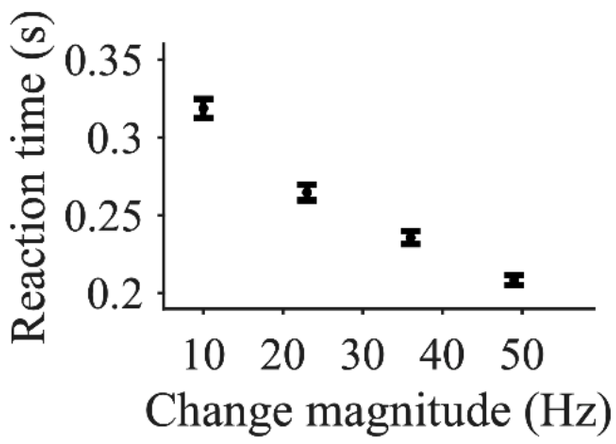


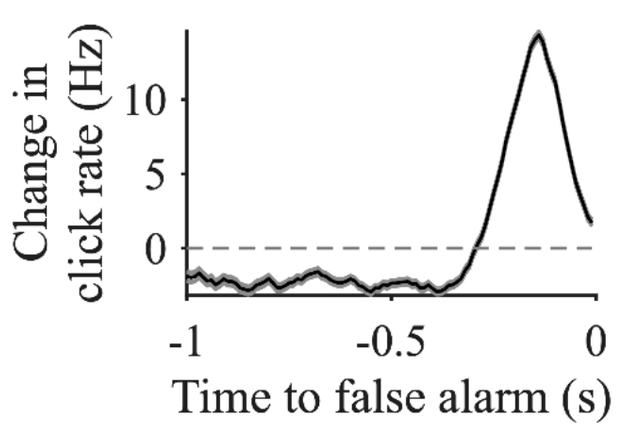
Erlich et al., 2015

Poisson clicks change detection task



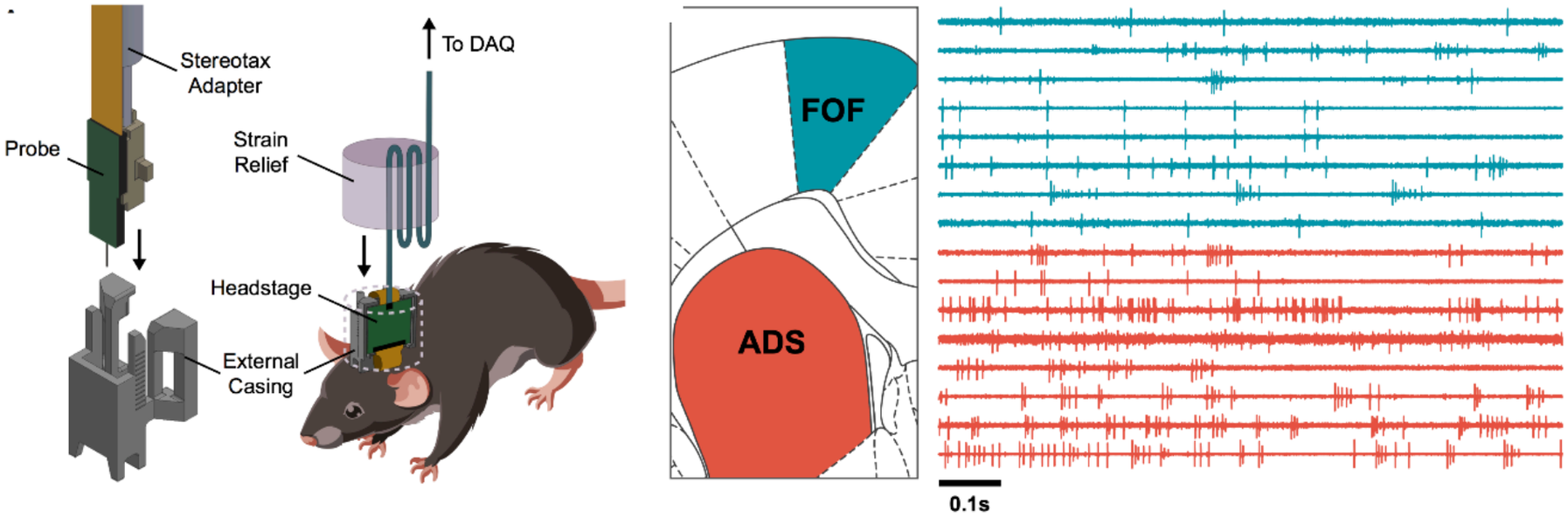






Goldring et al., 2025

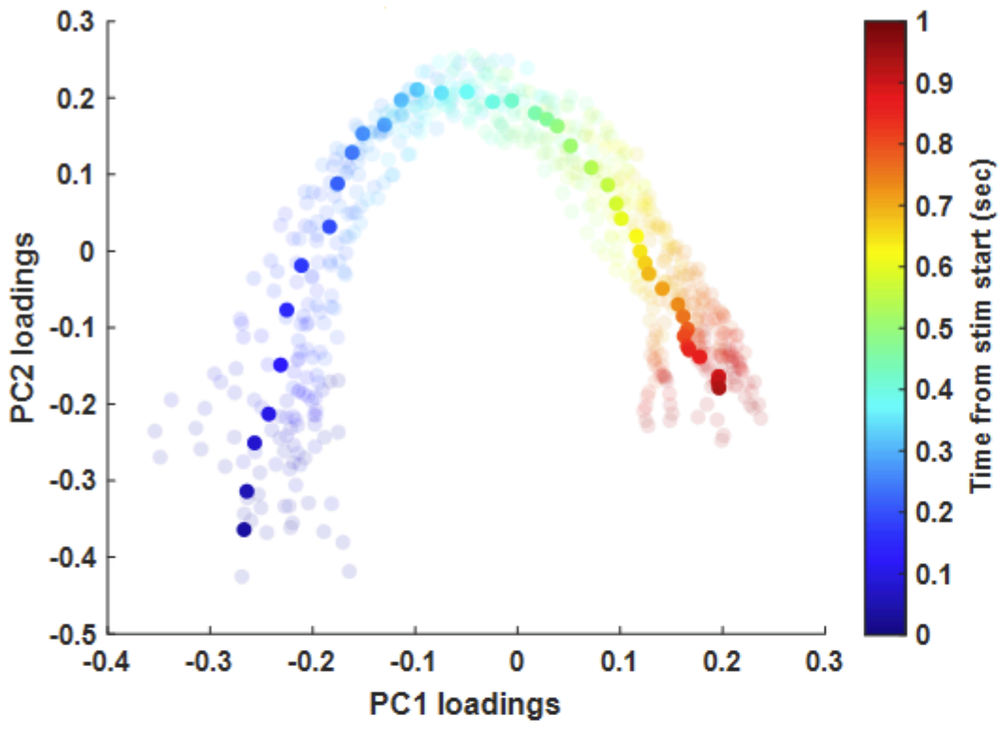
Neuropixels population recordings across rat frontal cortex and dorsal striatum



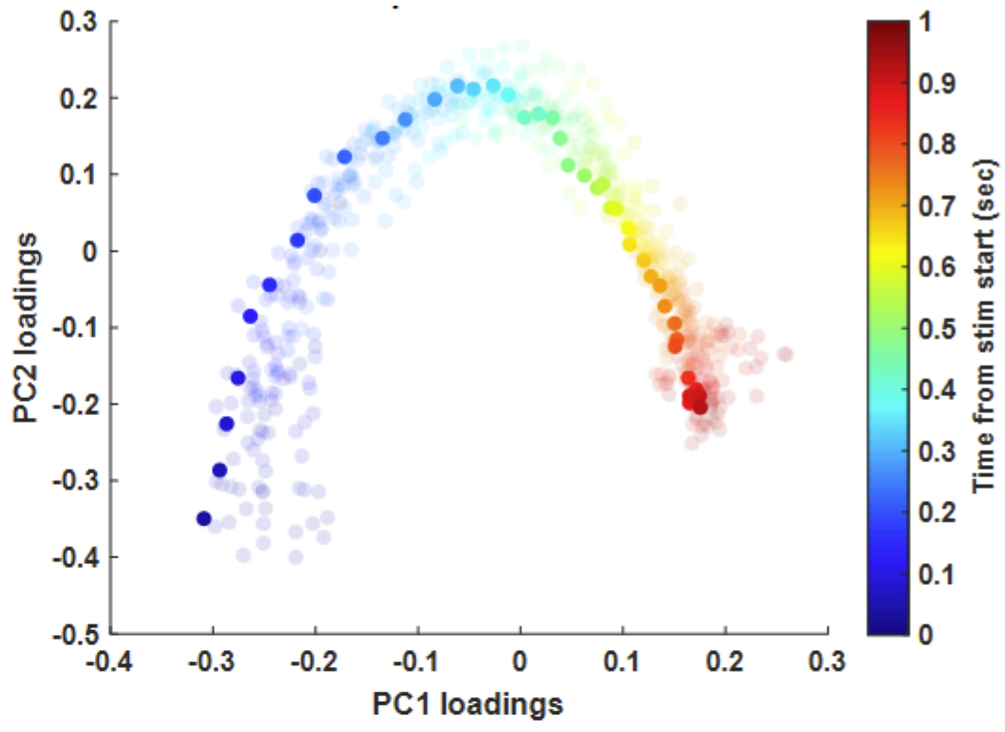
Goldring et al., 2025

Cortical and striatal activity show similar stereotyped trajectories over trial

Dorsal striatum (ADS)



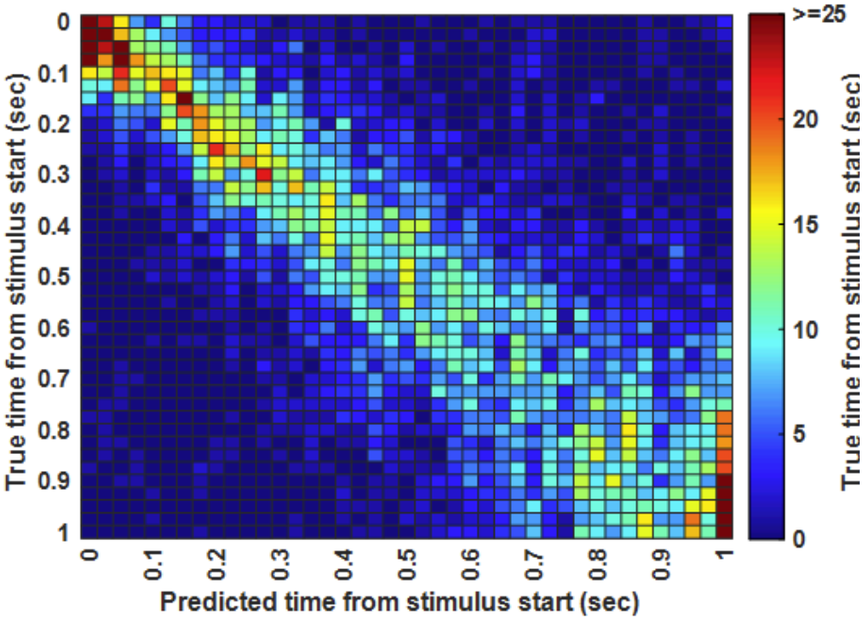
Frontal cortex (FOF)

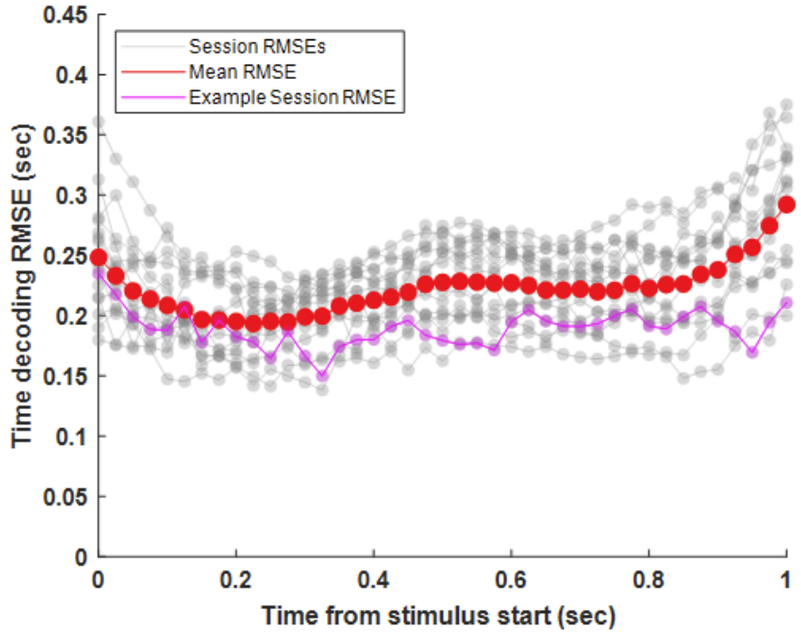


Trajectories encode elapsed time from stimulus start

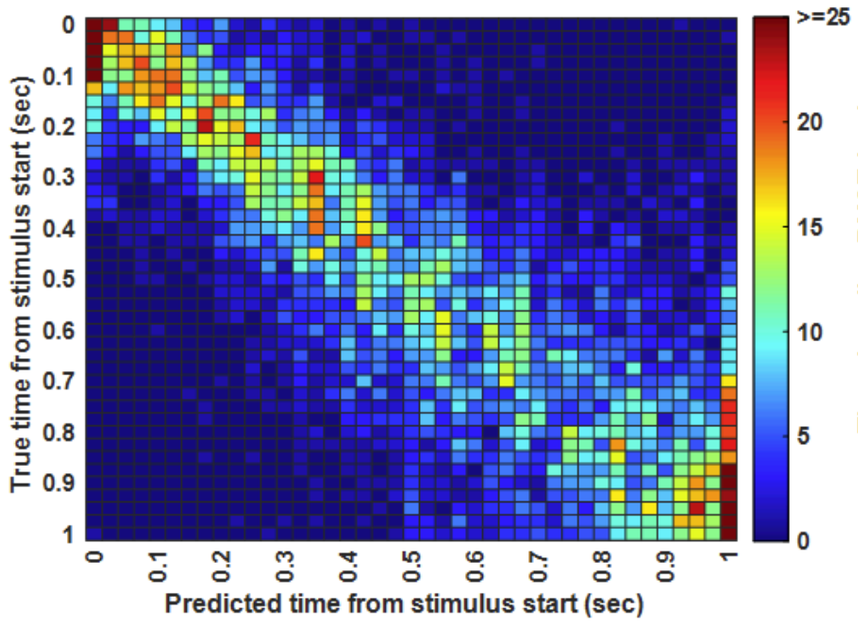
- Time is linearly decodable
- Similar performance across areas

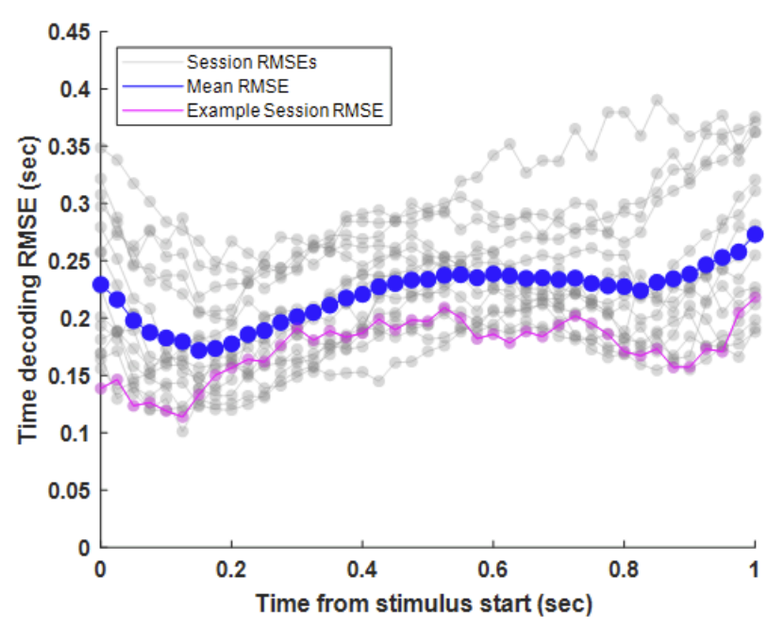
Dorsal striatum (ADS)





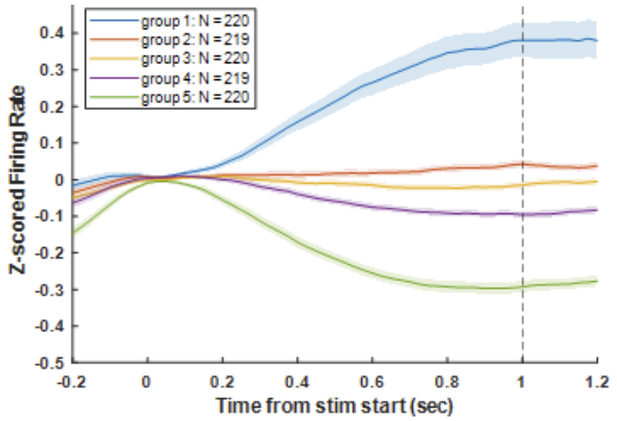
Frontal cortex (FOF)

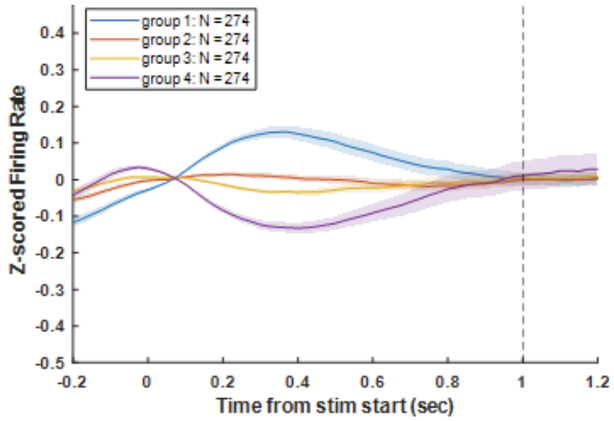


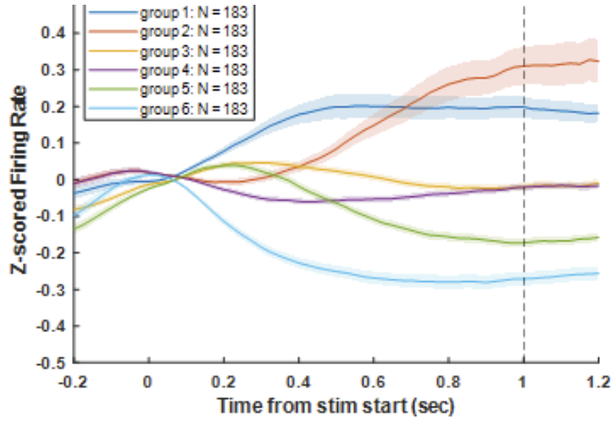


Classification of neurons by decoder weights reveal ramps and transient dynamics

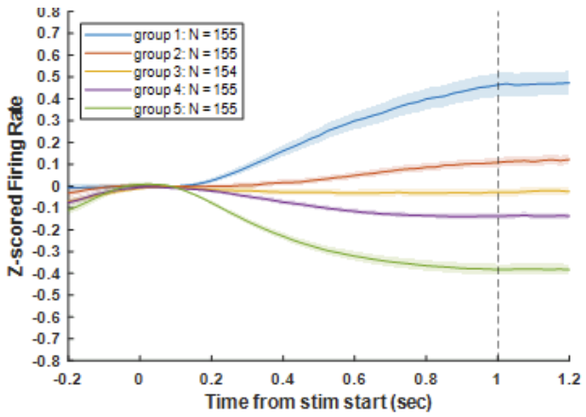
Dorsal striatum (ADS)



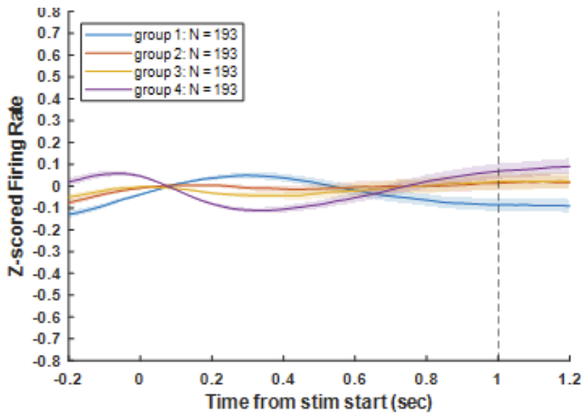




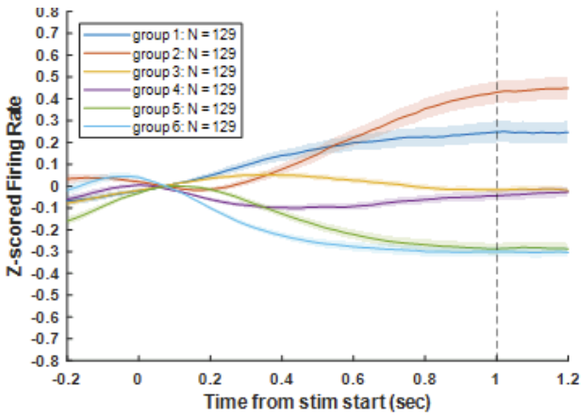
Frontal cortex (FOF)



Grouped by first mode

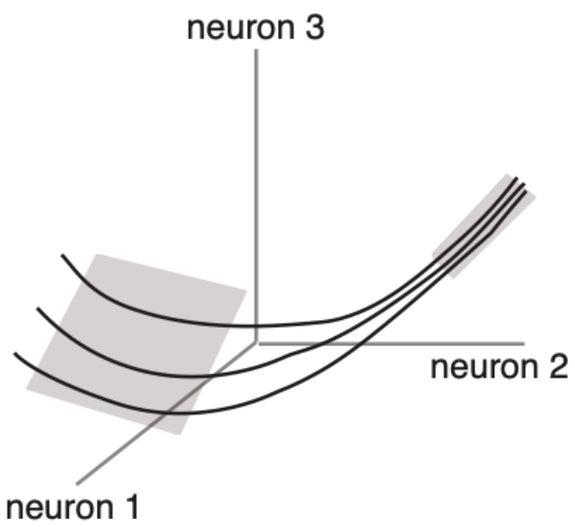


Grouped by second mode

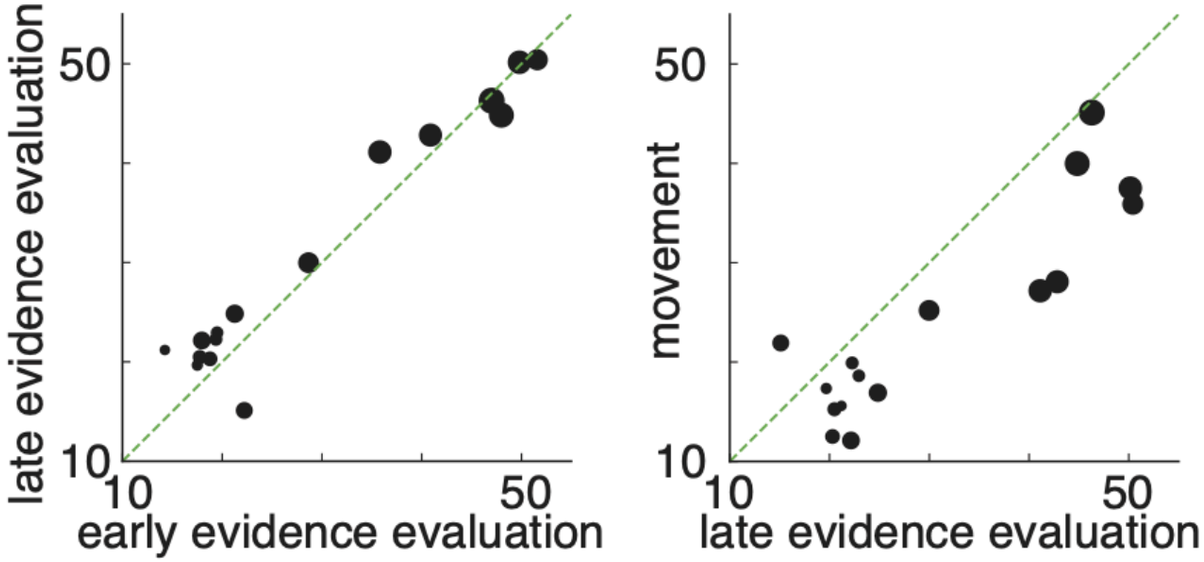


Grouped by first two modes

Trajectories collapse to lower-dimensional subspace upon decision commitment movement



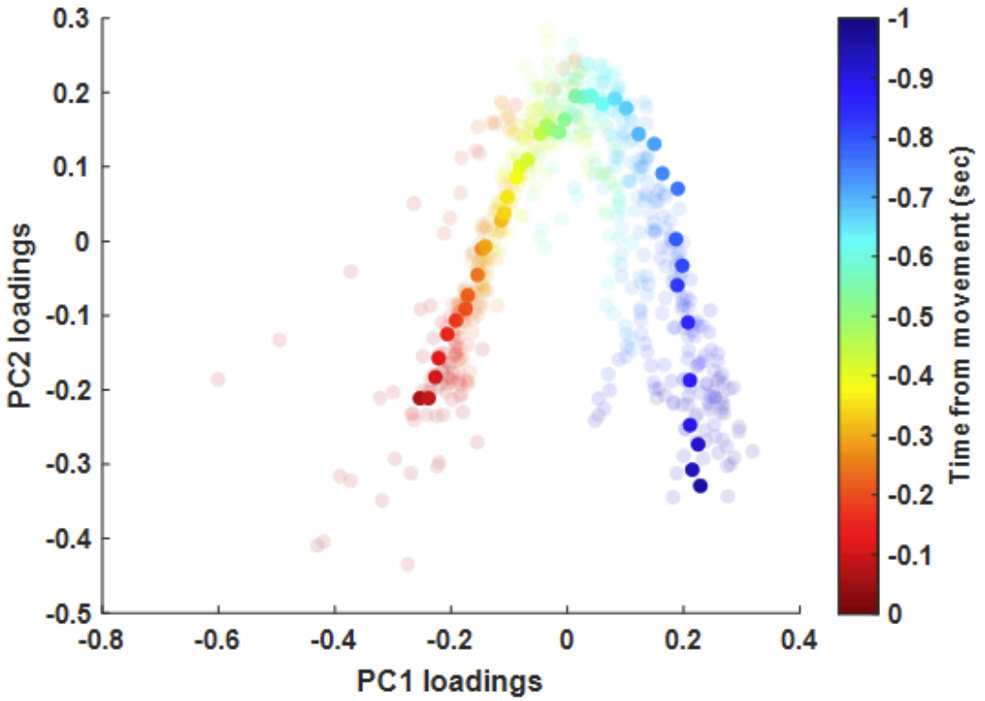
dimension comparison



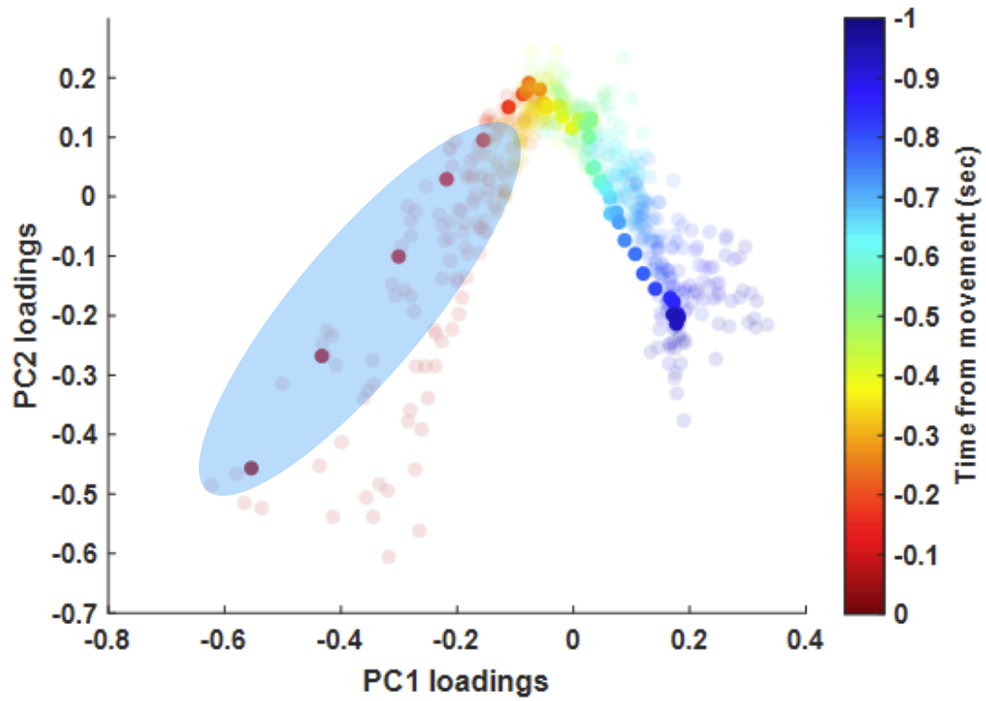
dimension estimated by participation ratio

Cortex and striatum diverge near time of decision commitment and movement initiation

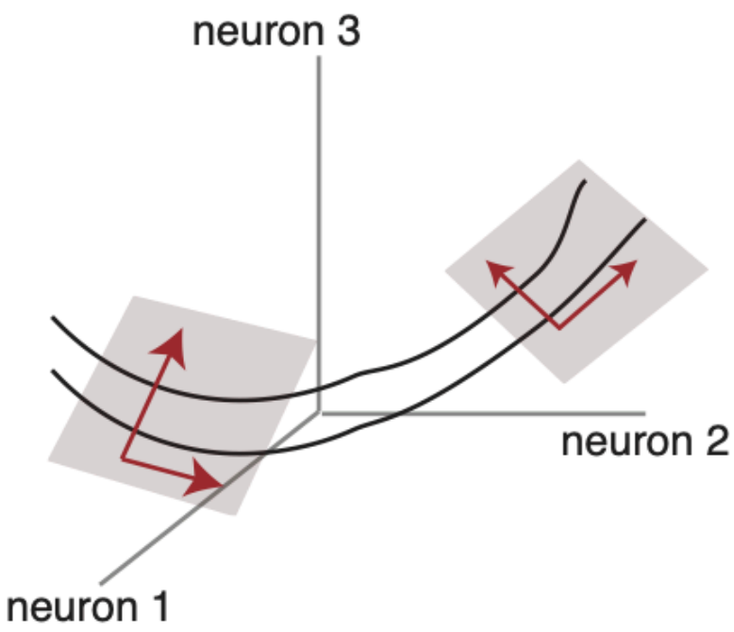
Dorsal striatum (ADS)

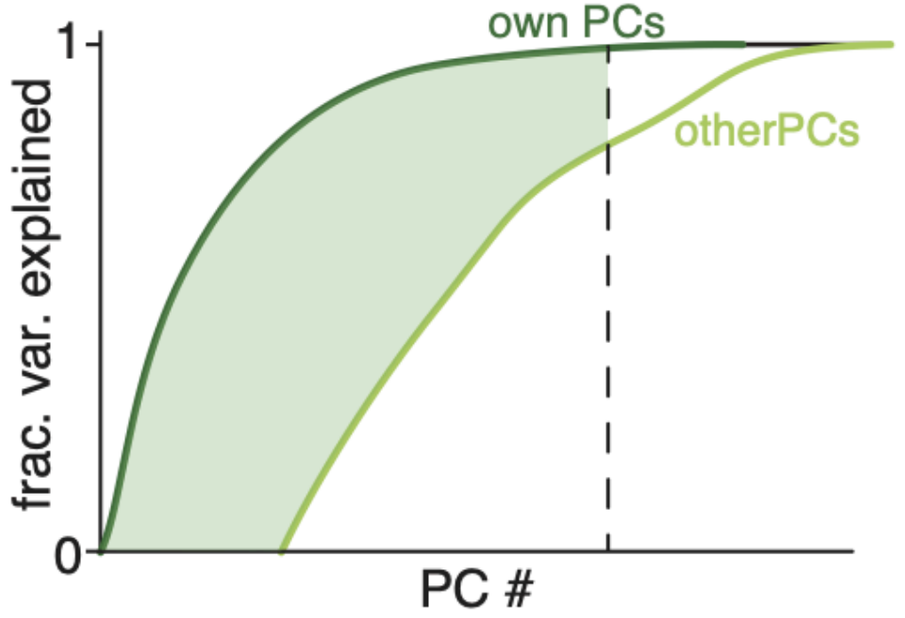


Frontal cortex (FOF)



Cortical dynamics rotate into new subspace near decision commitment movement

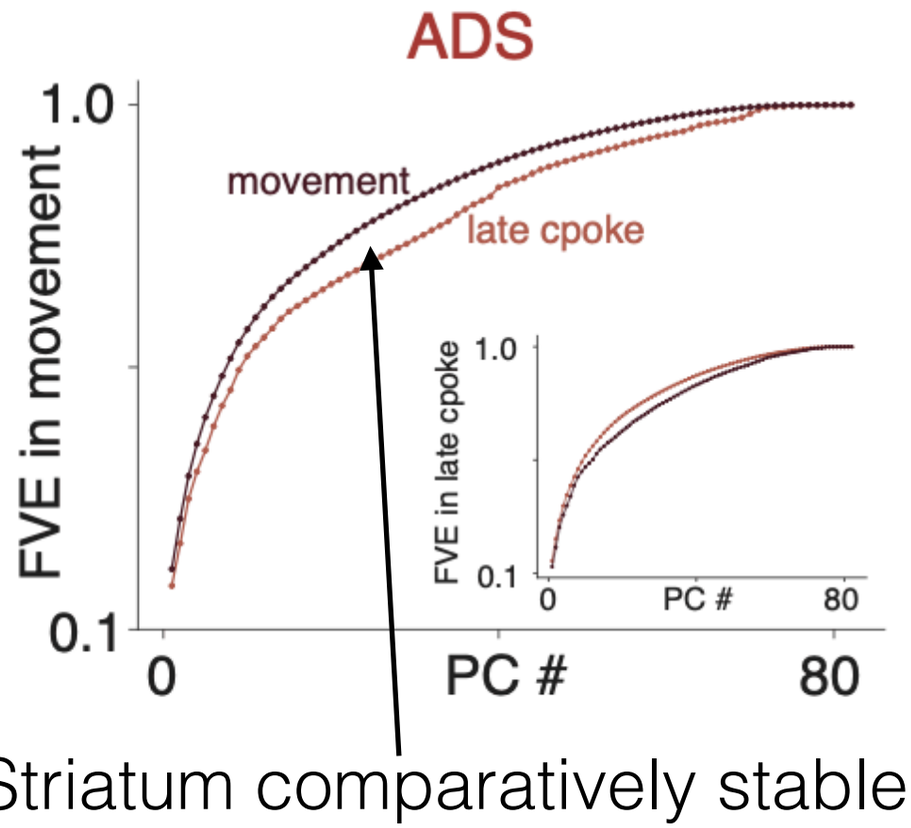




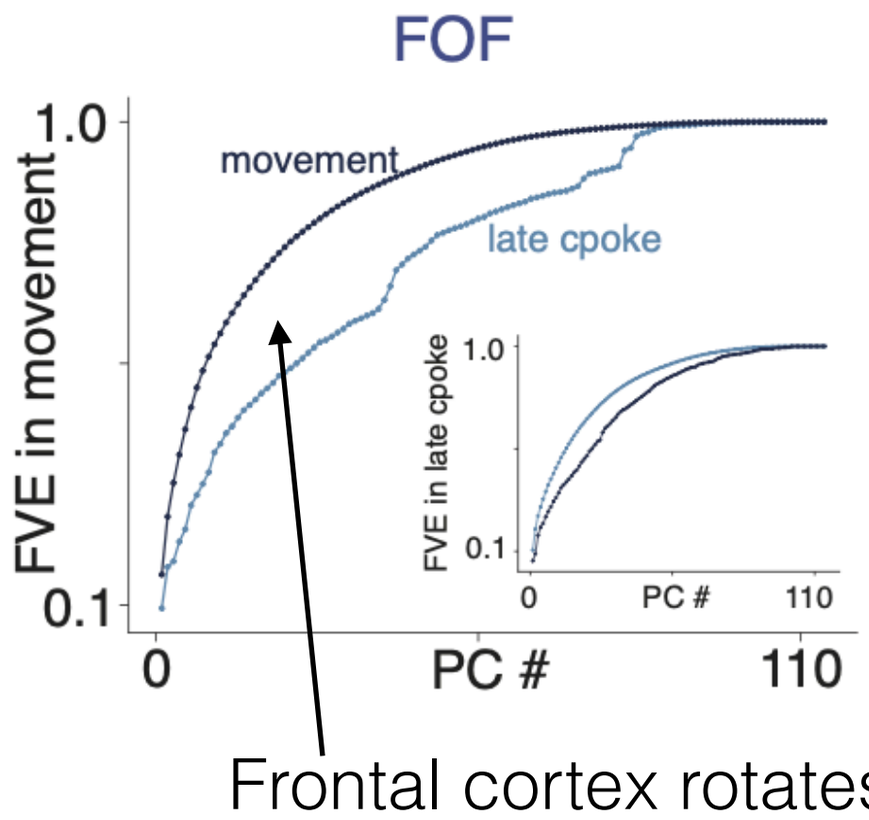
- Construct an alignment index to compare local subspaces (inspired by Elsayed et al., 2016)

- Captures how direction of high variance (principal components) during one task epoch capture variance during another epoch

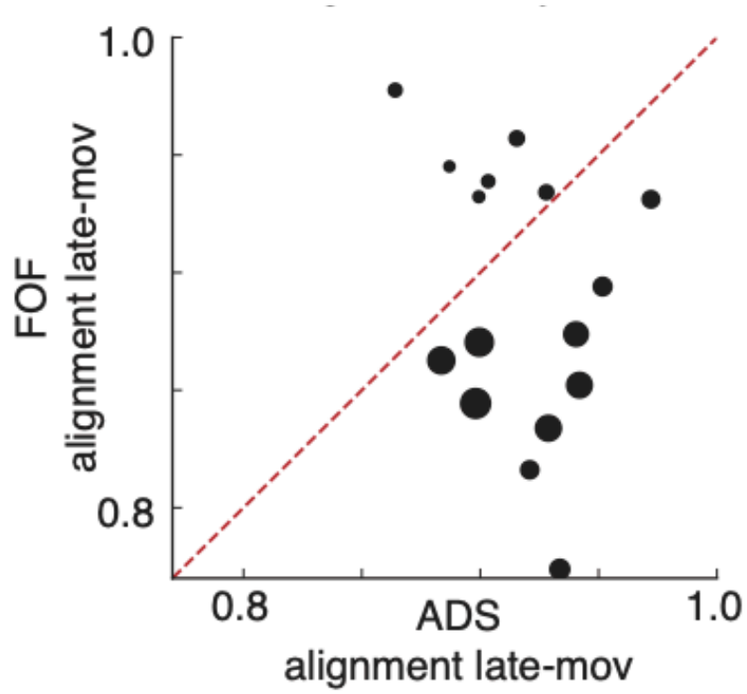
Cortical dynamics rotate into new subspace near decision commitment movement



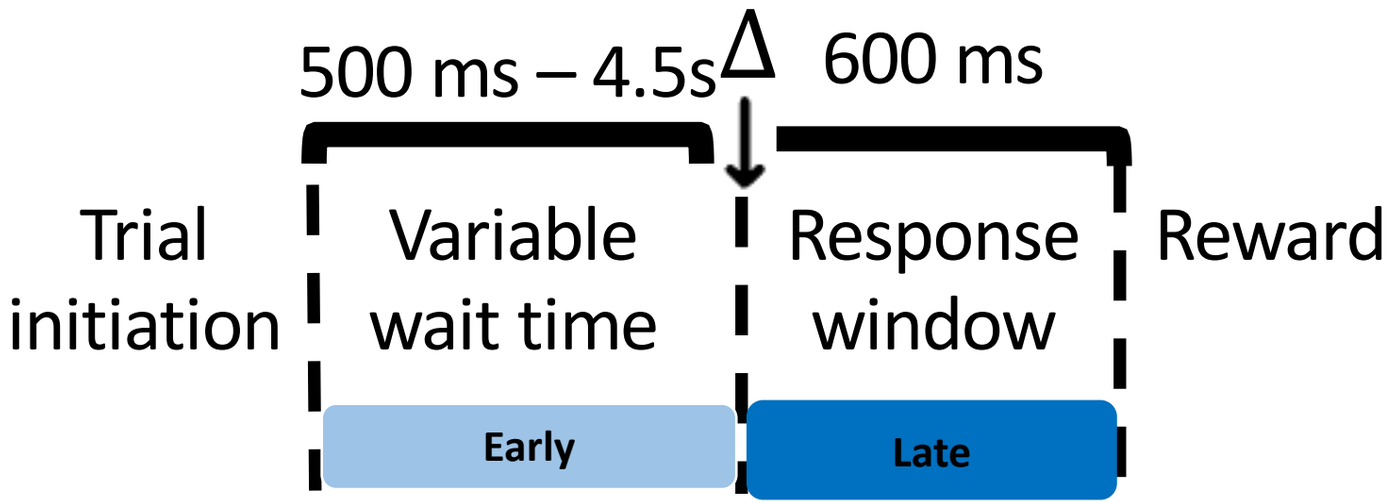
Striatum comparatively stable

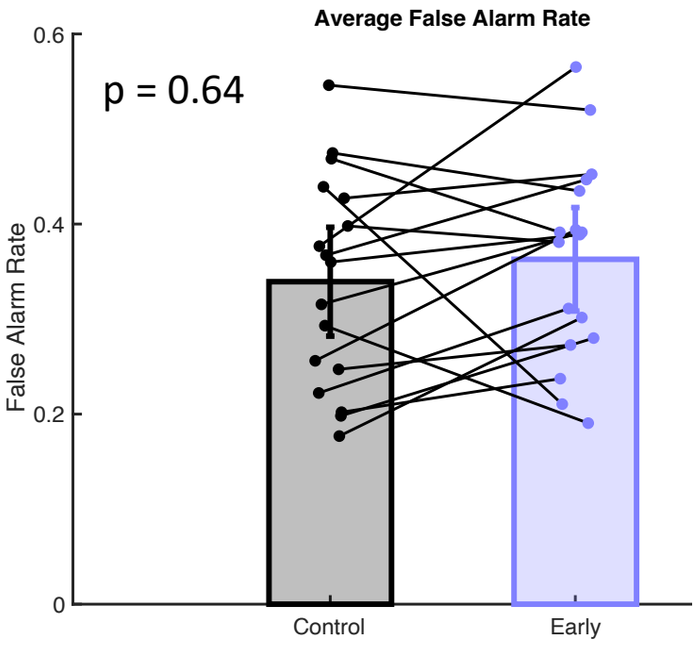


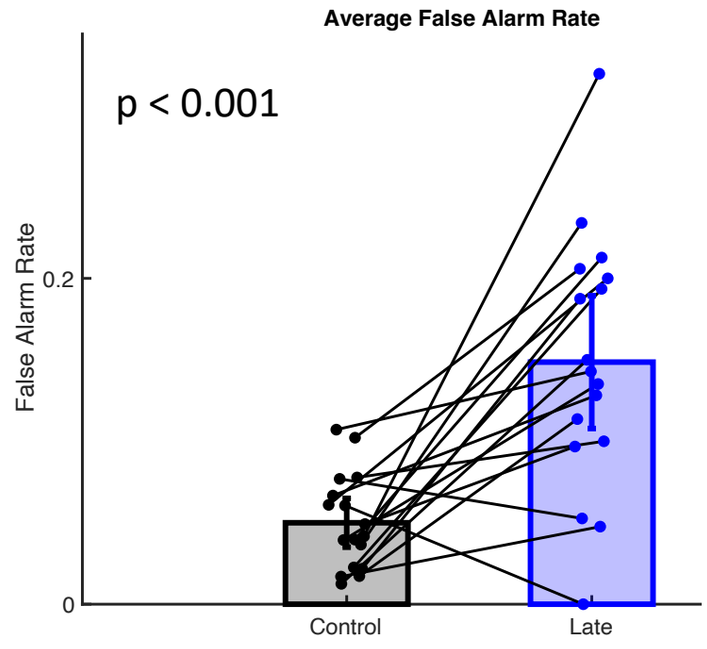
Frontal cortex rotates



Optogenetic inactivation of frontal cortex suggests role in withholding decision response







Nov. 16, 2025, 8:00 AM - 12:00 PM
PSTR088.11 - A contributory role for the rat frontal orienting field (FOF) in withholding free response decisions

Kendall Stewart
(Hanks lab)

Basic questions about this distributed network

- What dynamical regime is the network operating in?

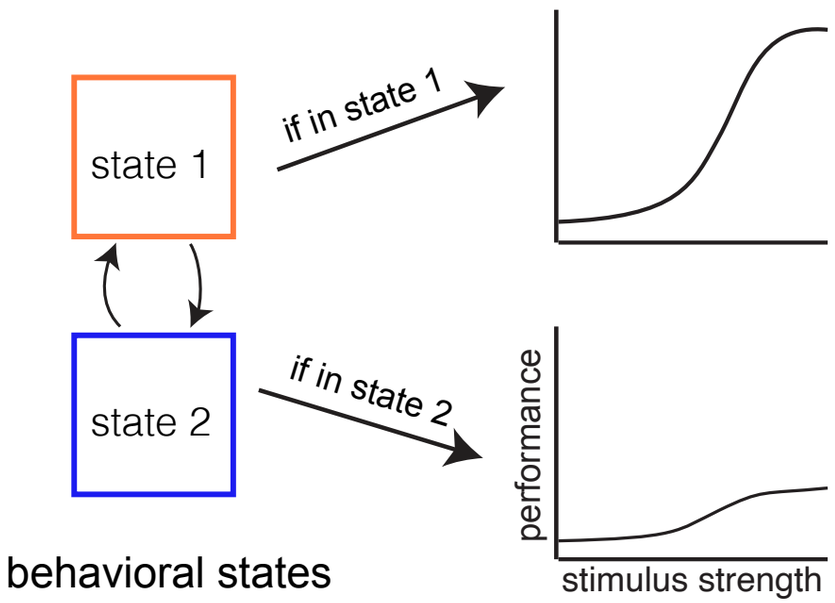
  Activity follows stereotyped nonlinear paths, suggesting dynamic coding by internally-generated neural trajectories rather than static or predominantly stimulus-driven representations.

- What are the differential roles of cortical and subcortical areas?

  Flexibly modulated cortico-striatal loop: frontal cortex and striatum tightly coupled, but cortex controls decision commitment

- How do these networks reconfigure across conditions and perturbations?

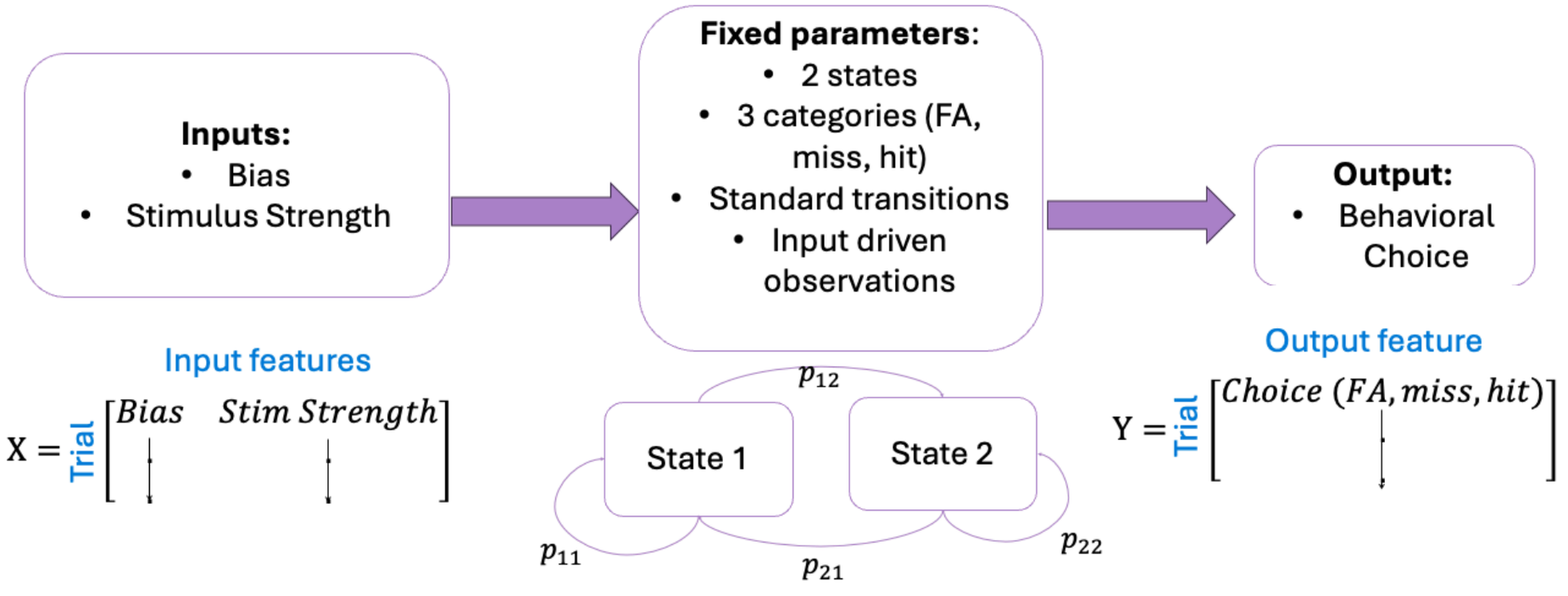
Latent variable model to capture underlying behavioral states during task



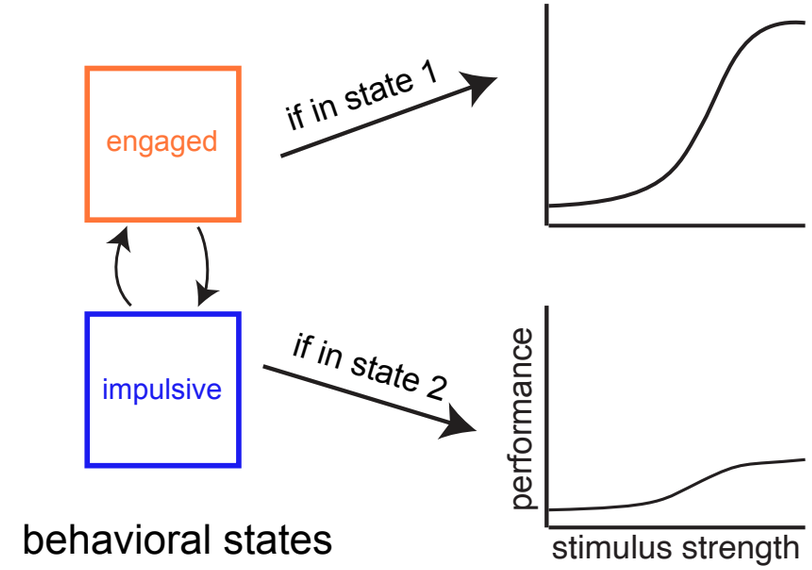
behavioral states
(modeled by HMM)

task input-output relationships

- Adapt Generalized Linear Model - Hidden Markov Model (GMM-HLM) (Calhoun et al., 2019; Ashwood et al., 2022)
- Latent states shape mapping between task inputs and outputs

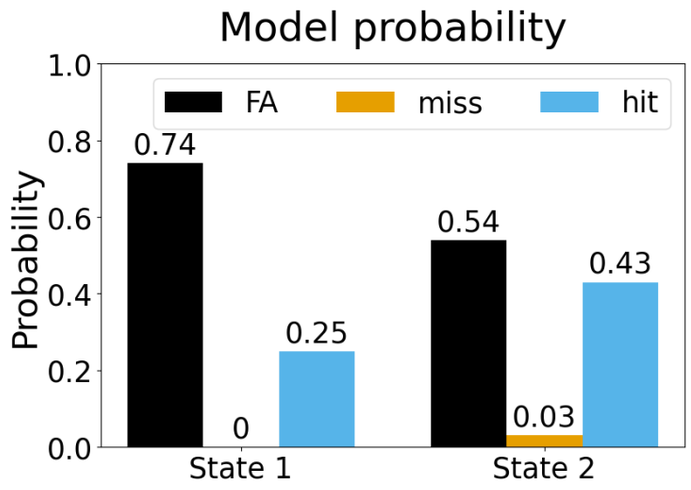


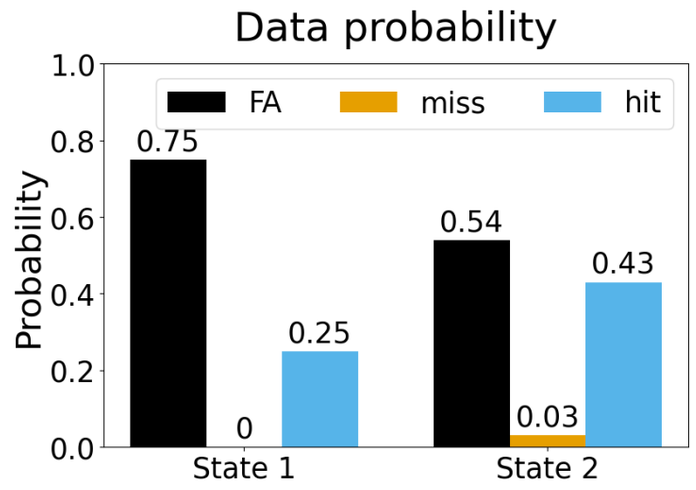
Rats alternate between a task-engaged and an impulsive state

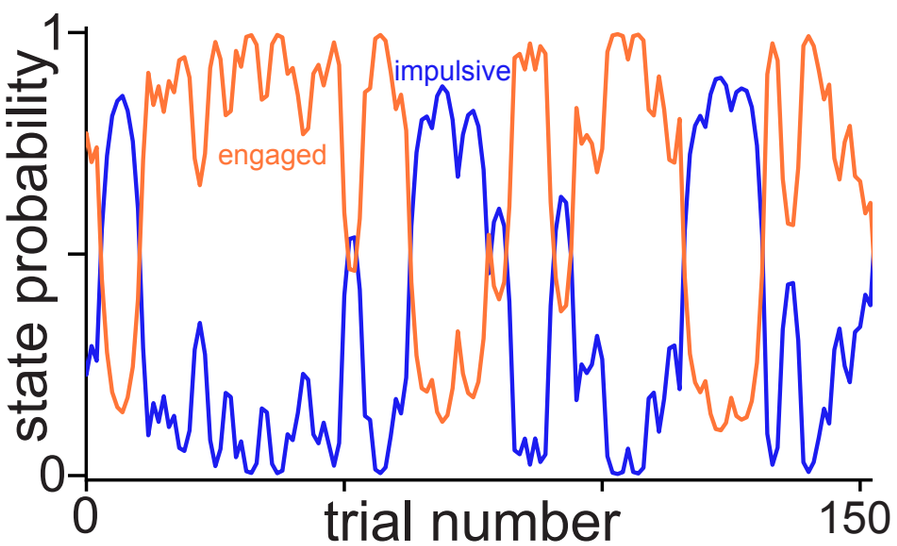


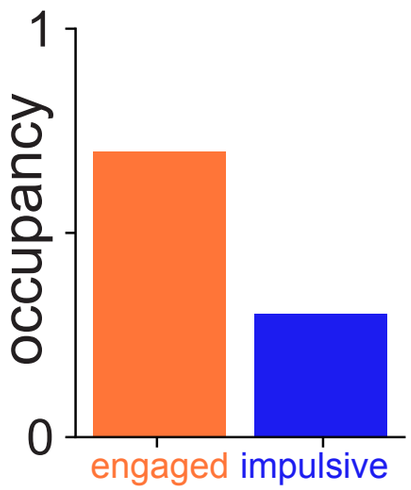
behavioral states (modeled by HMM)

task input-output relationships



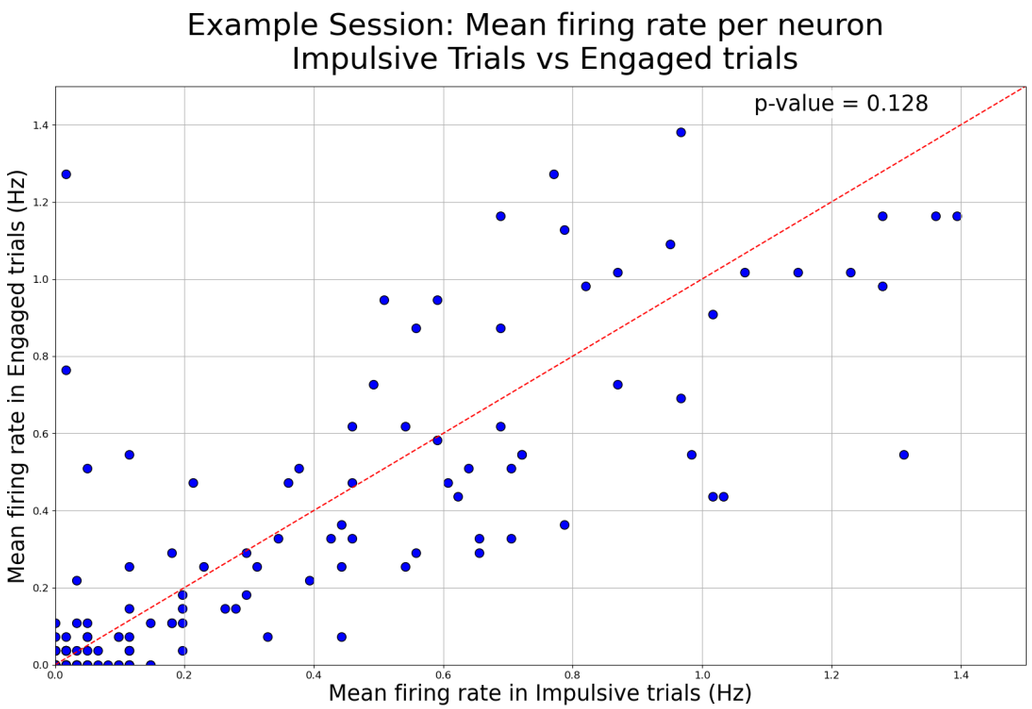




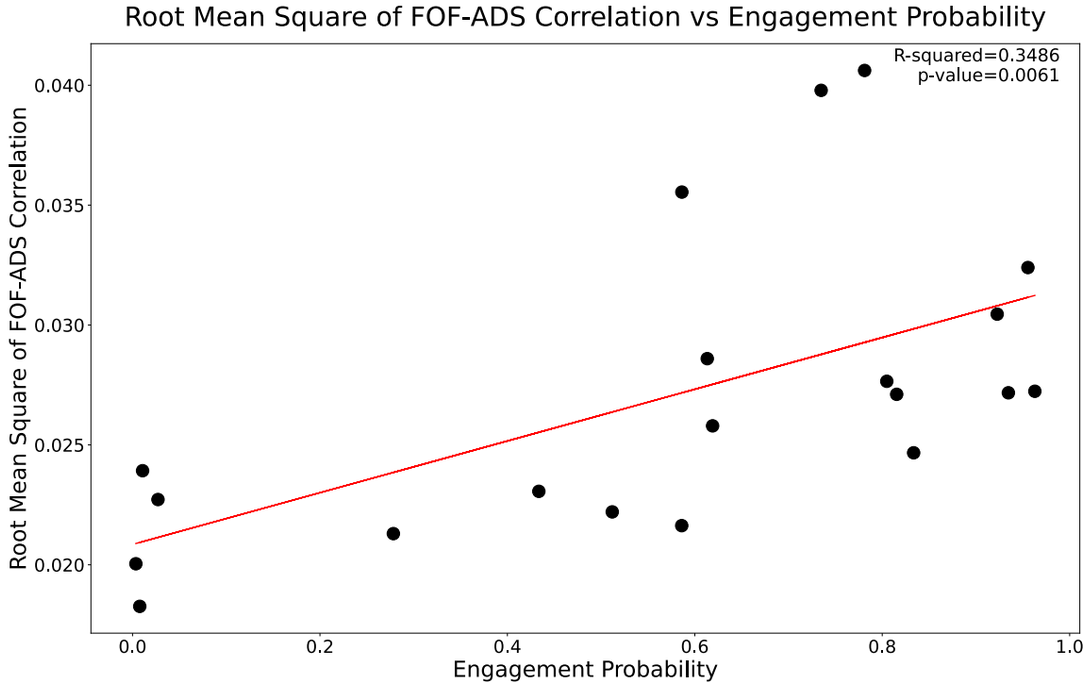


- Engaged state is responsive to evidence
- Impulsive state is false alarm prone

Behavioral state reflected in fronto-striatal coupling strength but not in mean firing rate



(Points not significantly off of y=x line)



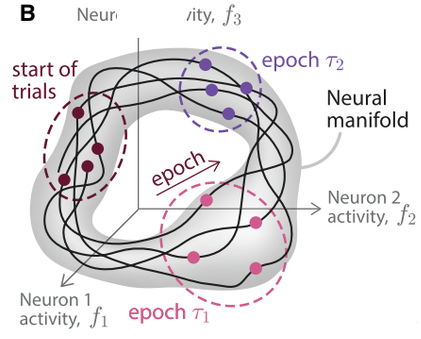
(Slope significantly different from 0)

Nov. 16, 2025, 8:00 AM - 12:00 PM
PSTR088.12 - From impulsivity to engagement: latent behavioral states modulate neural dynamics in perceptual decision-making

Aya Akhmetzhanova
(co-mentored with Hanks)

Conclusions

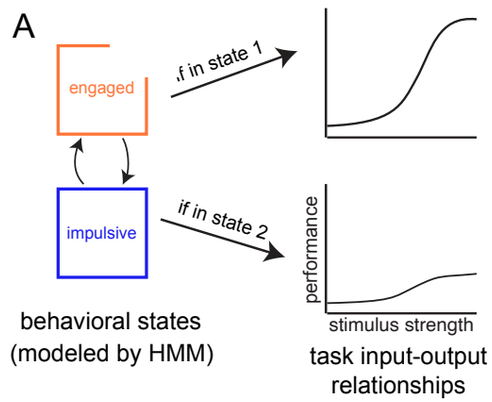
- Sequence coding: activity follows stereotyped nonlinear paths, suggesting dynamic coding by internally-generated neural trajectories rather than static or predominantly stimulus-driven representations.



Koay et al., 2022

- Basic anatomical unit of computation seems to be a flexibly modulated cortico-striatal loop: frontal cortex and striatum tightly coupled, but cortex controls decision commitment

- Rats switch between engaged and impulsive behavioral states, with corresponding changes in fronto-striatal coupling



- Highly-dynamic and distributed decision-making circuit that is strongly shaped by internal state

Acknowledgements

Aya Akhmetzhanova
(co-mentored with Hanks)

Anandita De
(now at University of Oregon)

Tanner Stevenson
(co-mentored with Hanks)

Kayleigh Adams
(looking for postdocs)

Nov. 16, 2025, 8:00 AM - 12:00 PM
PSTR088.12 - From impulsivity to engagement: latent behavioral states modulate neural dynamics in perceptual decision-making

Nov. 19, 2025, 8:00 AM - 12:00 PM
PSTR421.03 - Curvature of neural manifolds reveals a tradeoff in encoding strategy

Adam Goldring
(Hanks lab)

Kendall Stewart
(Hanks lab)

Preetham Ganupuru
(Hanks lab, now at UCLA)

Nov. 16, 2025, 8:00 AM - 12:00 PM
PSTR088.11 - A contributory role for the rat frontal orienting field (FOF) in withholding free response decisions

National Science Foundation

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Thank you!