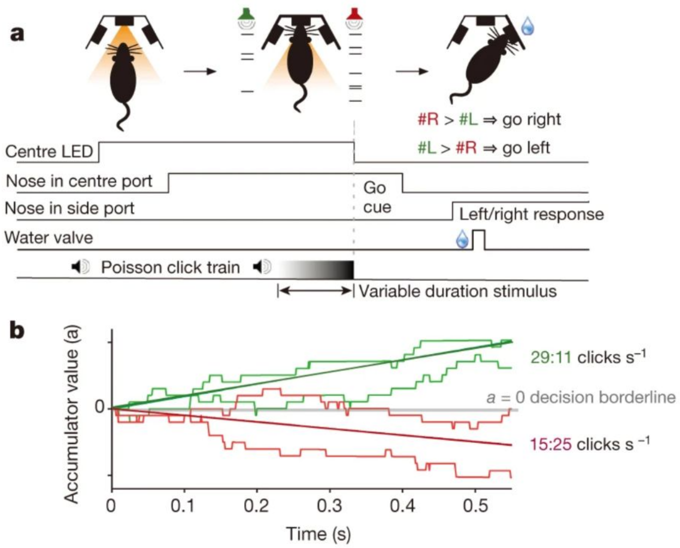
Coordinated cross-brain activity during accumulation of sensory evidence and decision commitment

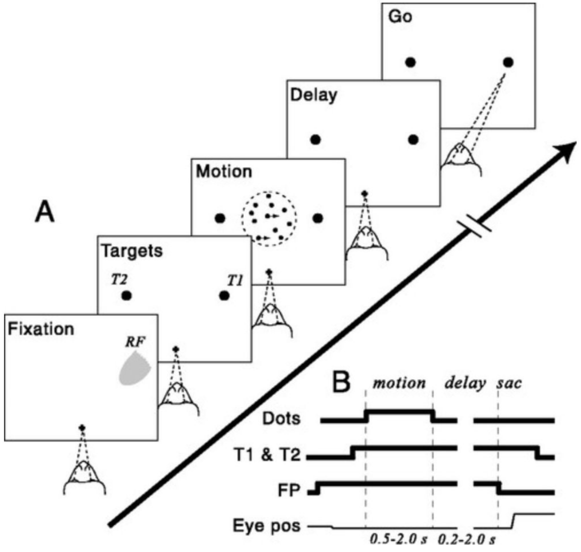
Fei & Charlie

02/13/2025

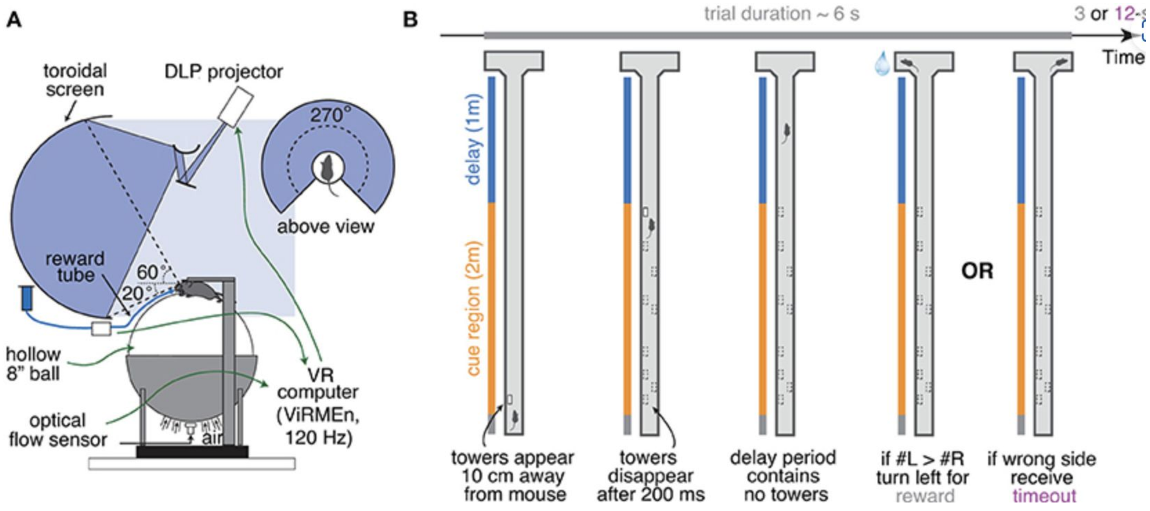
Decision Making Behavioral Paradigms



Hanks Kopec et al 2015

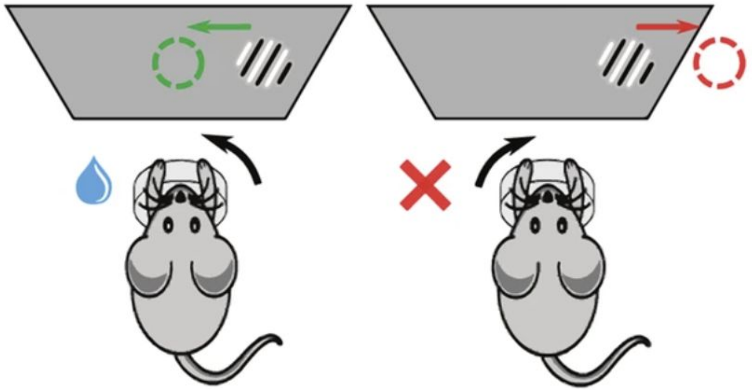


Shadlen and Newsome 2001



Pinto 2018

IBL 2021



Core elements of decision making behavioral paradigm

- Exposure to sensory evidence
  - Moving dots or grating
  - Olfactory stimuli
  - Auditory clicks
- Delay Period
- Go Period (Cue) - motor
  - Eye saccades (shadlen newsome 2001)
  - Lick Direction
  - Lick Rate
  - Forelimb reaches
  - Locomotion

Prior/ongoing Work

- Many brain regions studied individually
- Rat Frontal Eye Fields
- MT, LIP in Monkey
- Striatum, PPC, mPFC, dmFC
- International Brain Laboratory
    - **Pooled** neuropixel recordings from many labs
    - 241 brain regions
- So why large scale *simultaneous* recordings?

Motivations for large scale simultaneous recordings

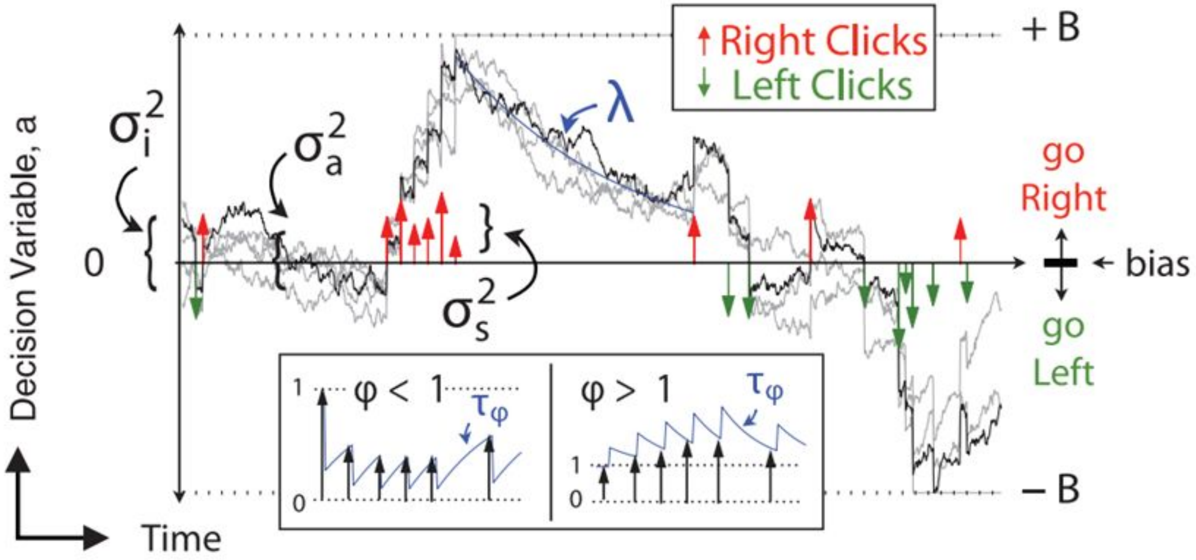
1. Network level activity - temporal features

- Signal correlations/synchronicity
- Do regions lead or lag each other
- Does one region predict another
- Shared latents?
- What is communicated between regions?

2. Single trials

- Pooled recordings depend on summary statistics of population activity
- Goal: understanding decision making, internal states, spontaneous behavior, etc. on single trials

Drift Diffusion Models



Previous Work on DDM

Cohen 2025

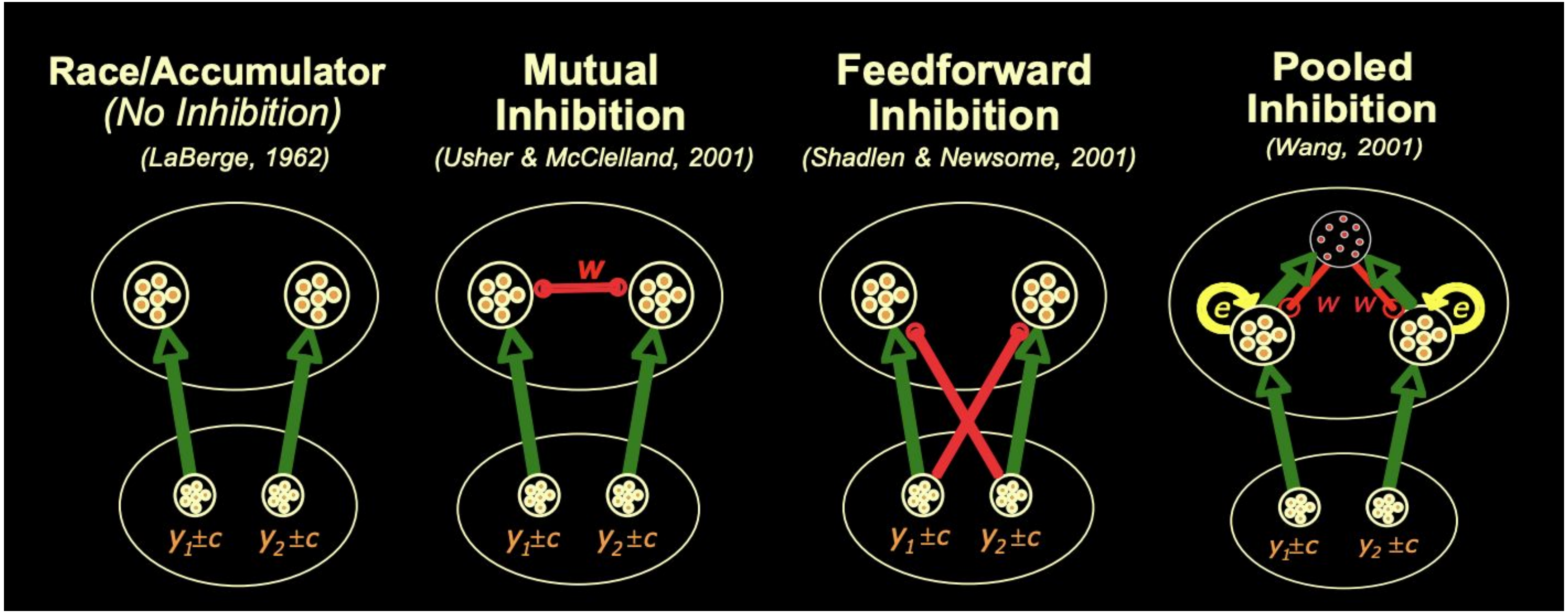


Figure 1: “Poisson Clicks” Task

A decision-making task that demands the gradual accumulation of momentary evidence

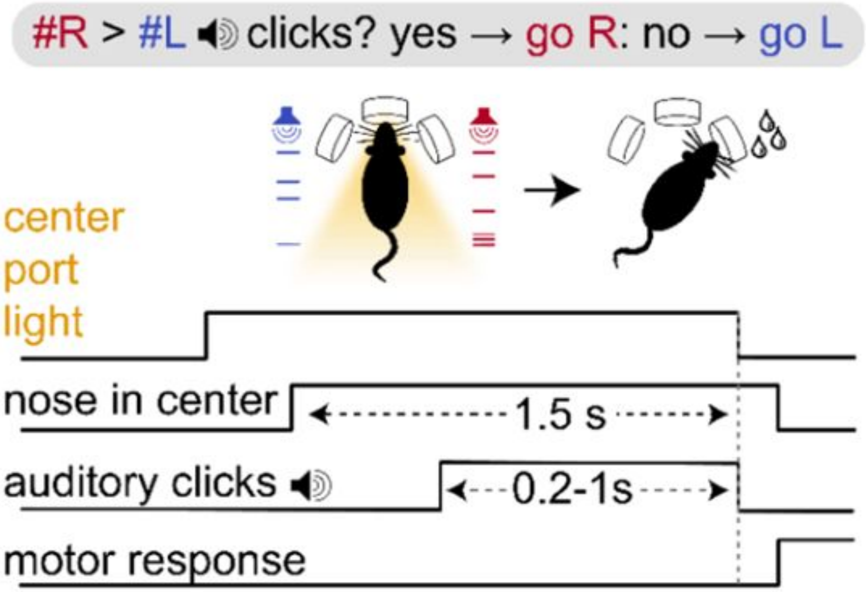
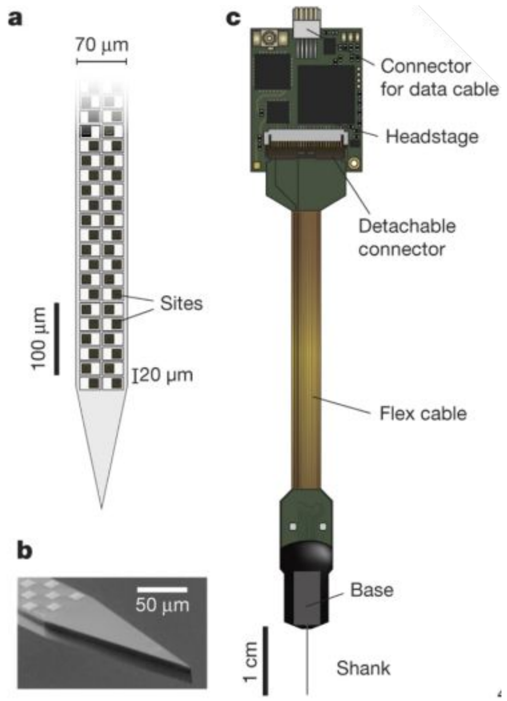
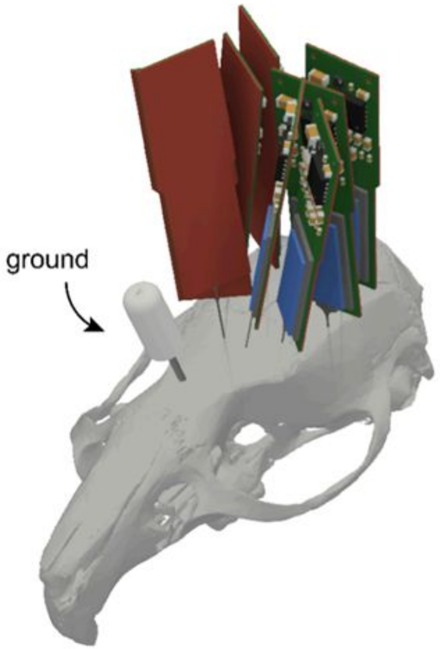


Figure 1: Simultaneous Multi-Region Neuron Recordings

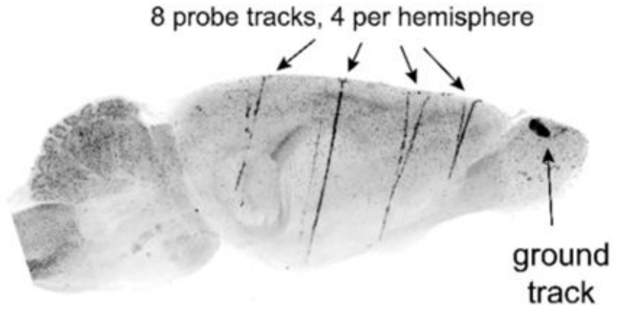


Neuropixels 1.0

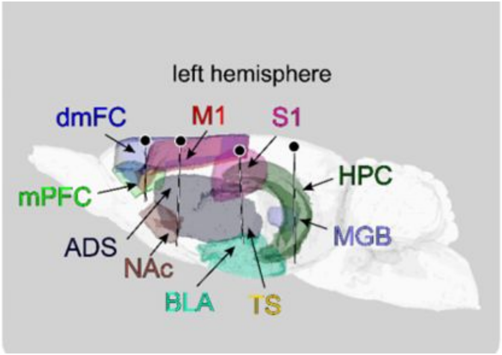
Jun et al 2017



8 Neuropixels probes on a rat's skull



Example rat histology



Probe penetrations registered to rat brain atlas

Decision Variable

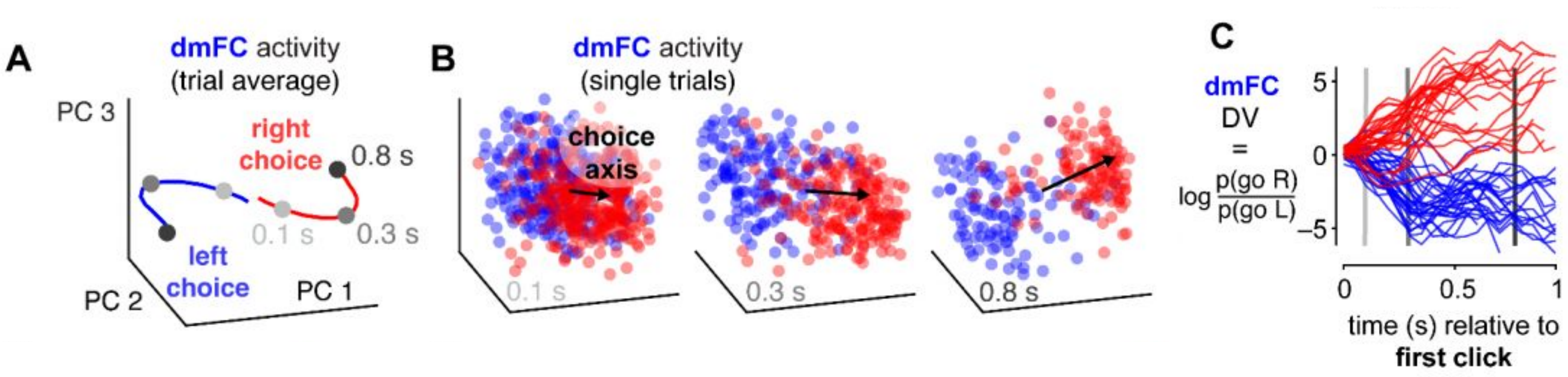
- Projection of neural activity onto its choice predictive axis
- Logistic Regression
  - X = neural activity
  - p = probability of rightward choice
- Set of coefficients for each time point of a trial
- Moment to moment estimate of choice encoding in a neural population

$$\ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n$$

$$DV_t = X_t\beta_t + \alpha_t = log(\frac{p(R)}{p(L)})$$

- Why use a decision variable? Why not analyze the properties of the raw firing rates? (or maybe their principal components?)

Figure 2

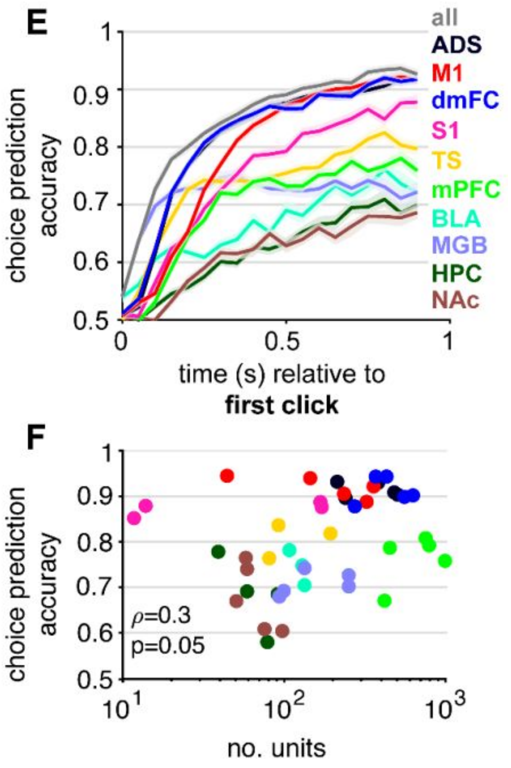


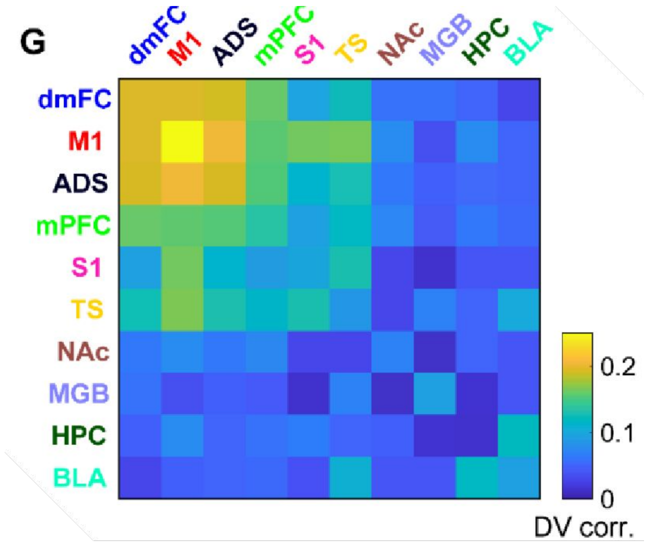
the vector of weights applied to each neuron

Probability of a rightward choice: $p(R) = f(X_t\beta_t + \alpha_t)$

Decision variable: $DV_t = X_t\beta_t + \alpha_t = log(\frac{p(R)}{p(L)})$

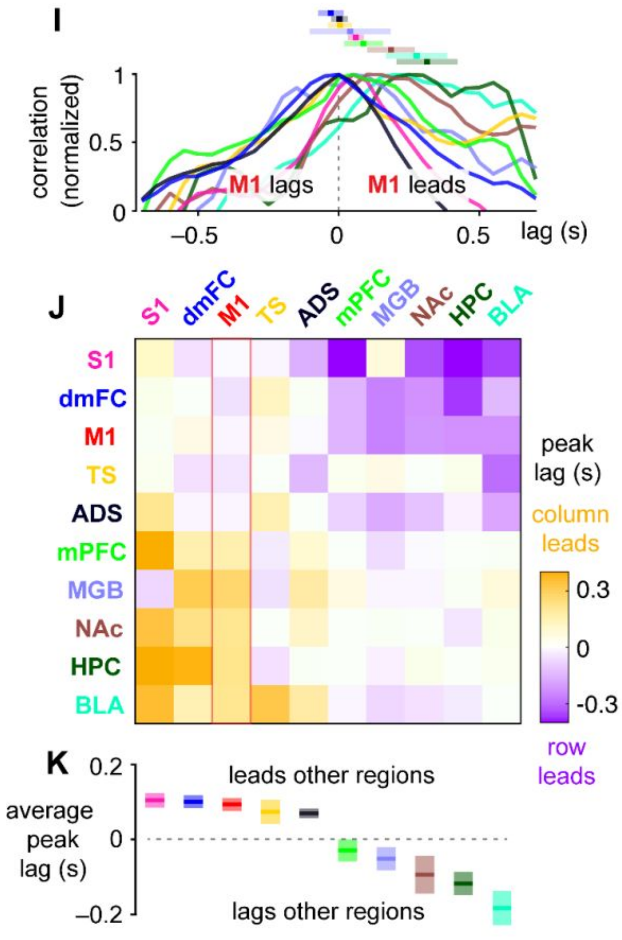
Figure 2



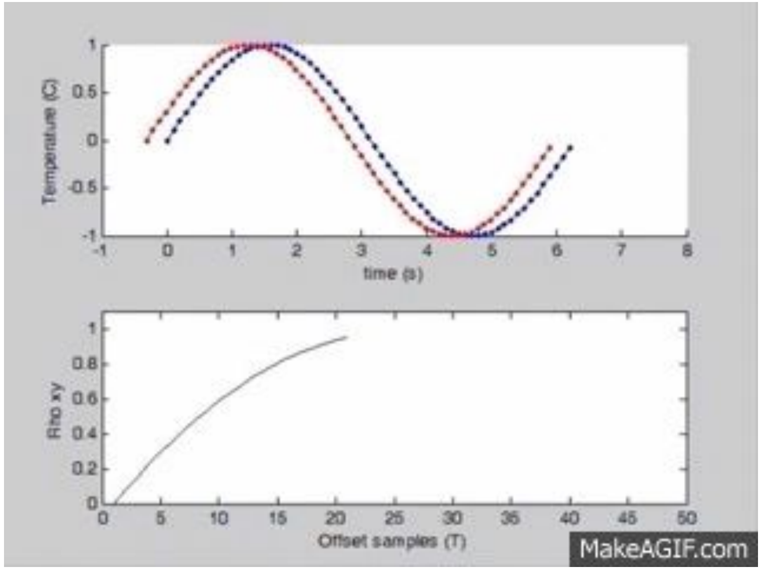


DVs were most highly correlated between ADS, M1, and dmFC

Temporal structure of DV correlations



Background - cross correlation



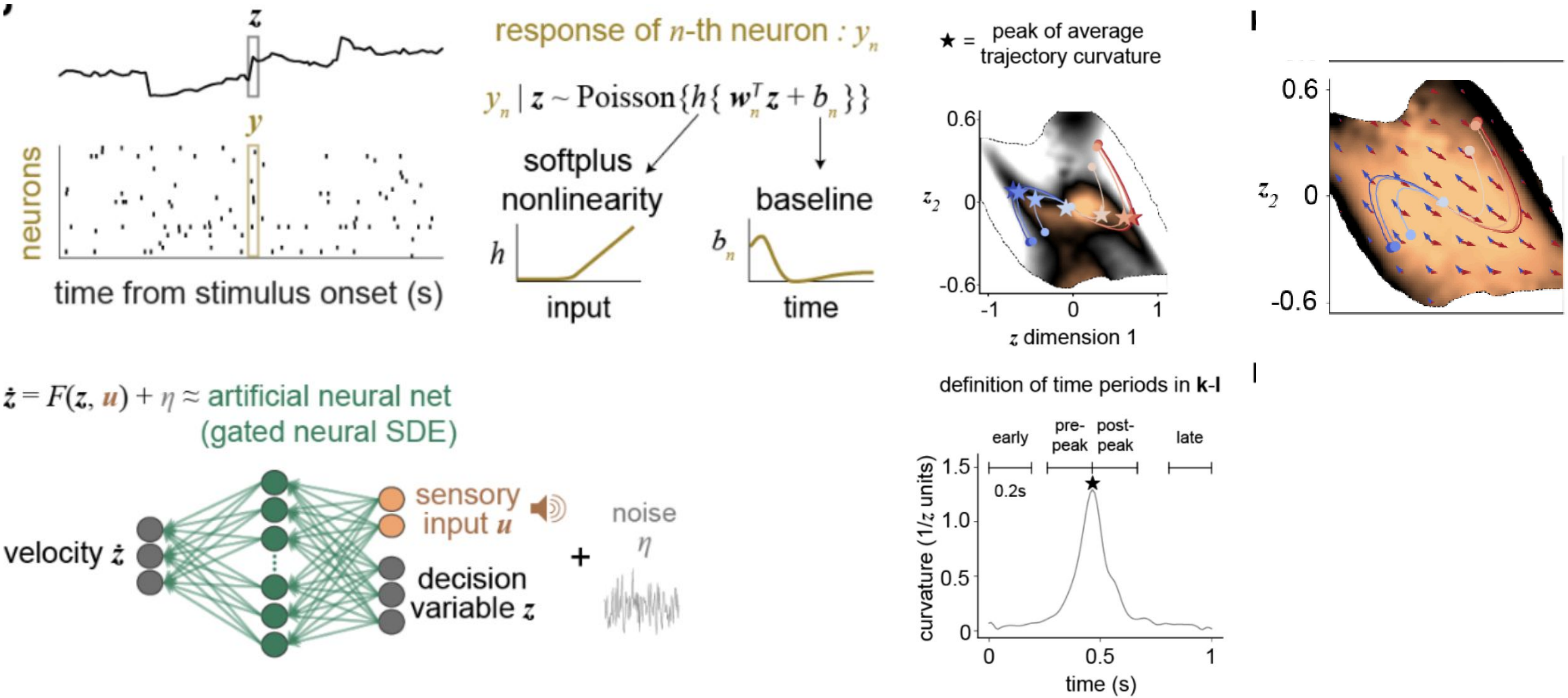
What is nTc (neural time of commitment)

- Why do we care about internal cues?

What is nTc (neural time of commitment)

- Why do we care about internal cues?
    - Neural “dark matter”
    - Large majority of neural data not explained by task variables and spontaneous movement
    - Internal states could be modulated by neuromodulators, experience, metabolic state, circadian rhythm, etc
    - What do we align neural activity to?

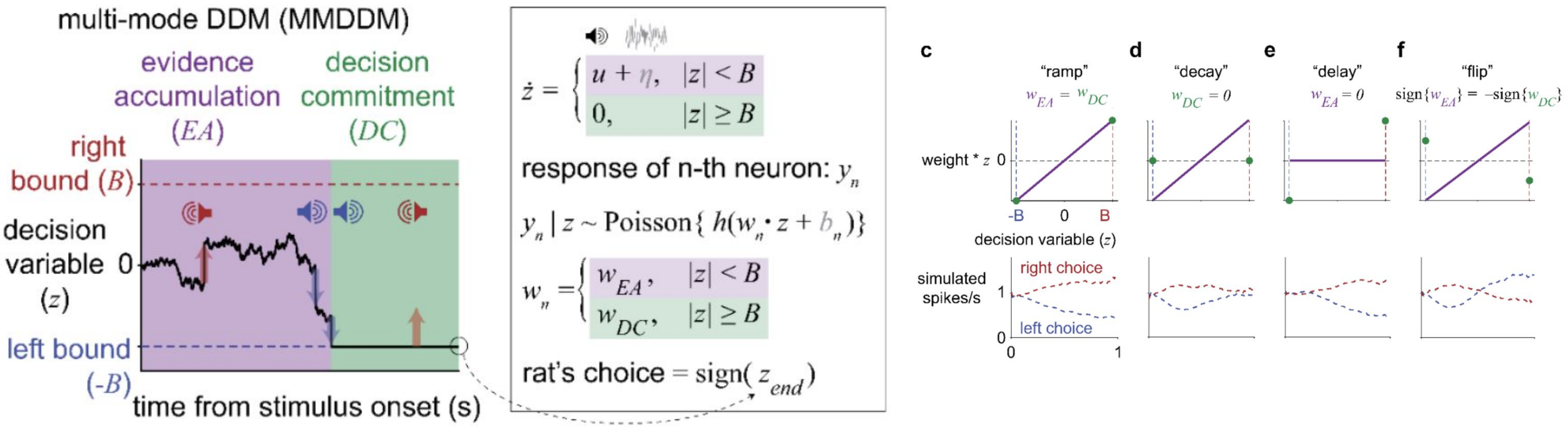
LUO 2023 -
nTC via FINDR



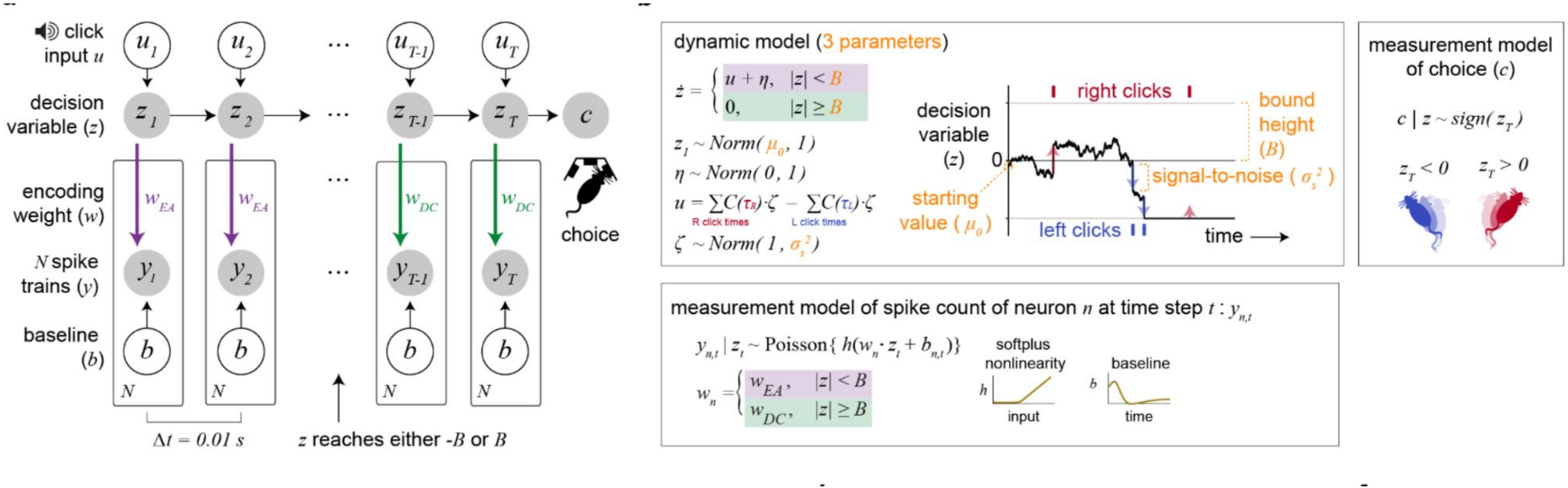
LUO 2023

nTC via MMDMM

- Multi mode DDM
  - DDM with two modes - Evidence accumulation, decision commitment
  - Two sets of weights W_ea W_dc
- Can capture different temporal profiles of neurons
  - DDM only captures ramping profiles

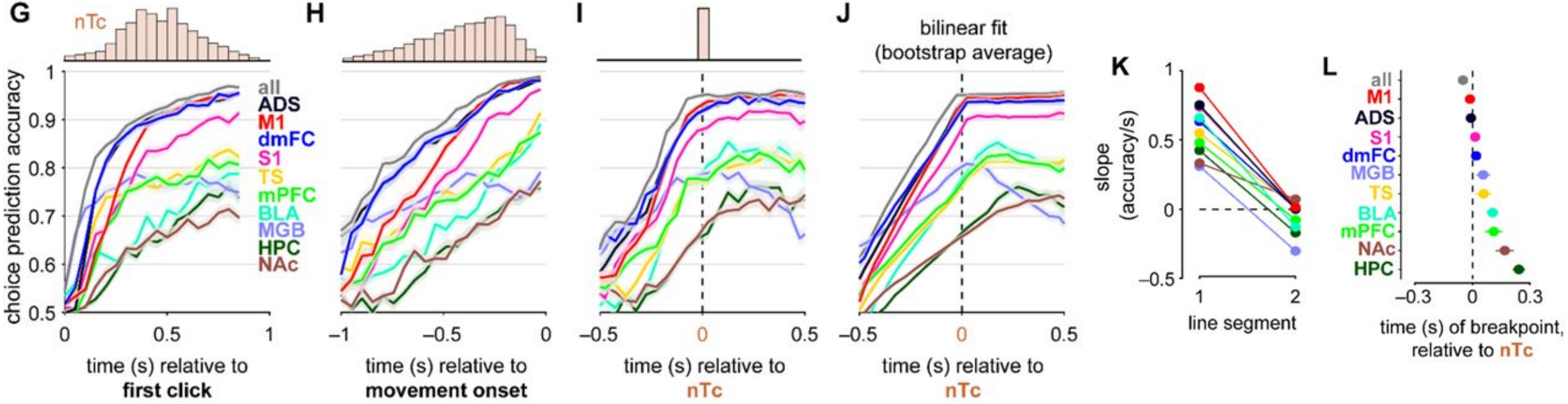


nTC via MMDMM



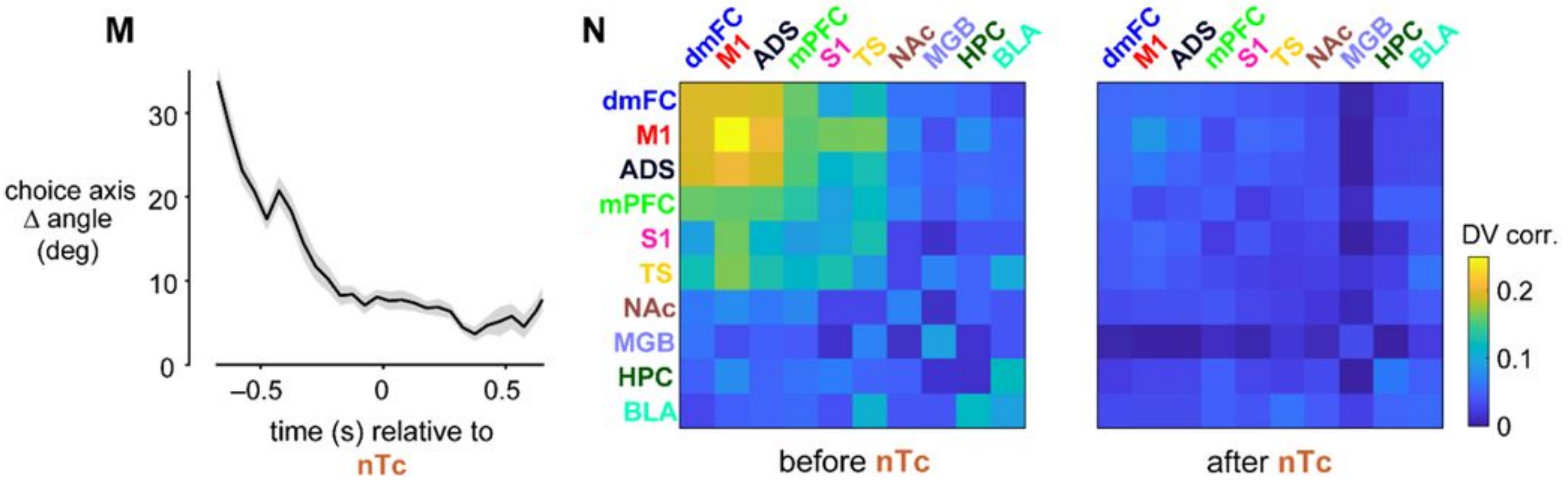
nTc = when P(z | y, u, w_ea, w_dc) >= 0.95

Figure 3: Cross-Brain Activity Change at nTc



Prediction accuracy of a logistic regression model of choice

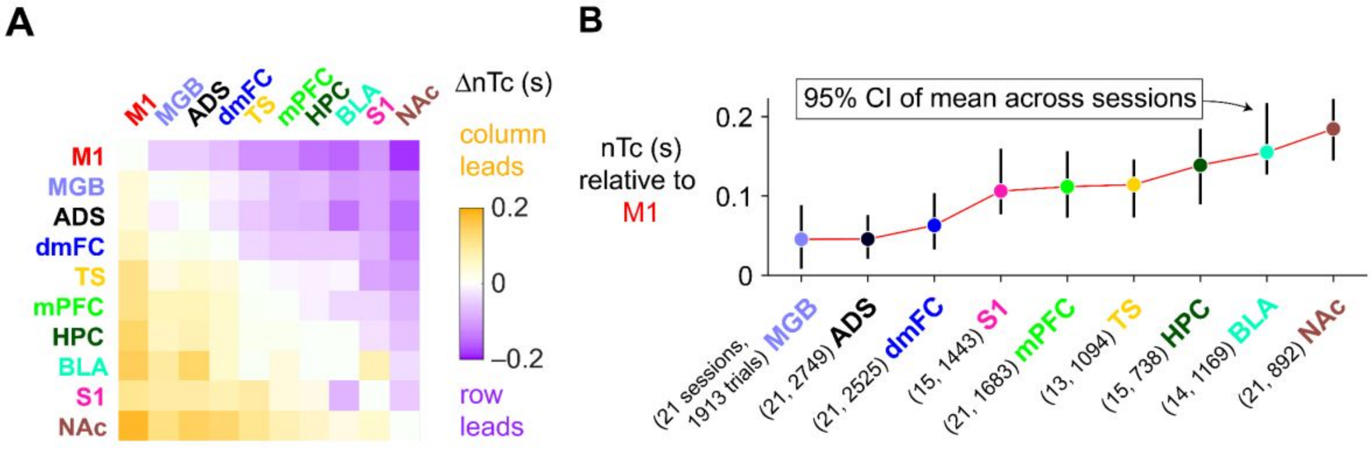
Figure 3: Cross-Brain Activity Change at nTc



The rotation of the choice axis in neural state space stabilized at nTc.

Inter-regional correlations along this axis dropped to near-chance levels after nTc

Figure 4: Decision Commitment is First Detected in M1



What are some interpretations of M1 being the earliest?

Questions?