# Neural population dynamics underlying a reach decision

Pierre-Olivier Boucher[1], Tian Wang[1], Laura Carceroni[3], Gary Kane[3], Krishna V Shenoy[5,6,7,8,9,10,11], Chandramouli Chandrasekaran[1,2,3,4]

[1]Department of Biomedical Engineering, [2]Center for Systems Neuroscience, [3]Department of Psychological and Brain Sciences, [4]Department of Anatomy & Neurobiology, Boston University, Boston, 02118, MA, USA

[5]Department of Electrical Engineering, [6]Department of Neurobiology, [7]Department of Bioengineering, [8]Stanford Neurosciences Institute, [9]Bio-X Program, [9]Department of Neurosurgery, [11]Stanford University/HHMI, Stanford University, Stanford, 94305, CA, USA

Manuscript preprint

Lab website

## Introduction

• We tested the hypothesis that a dynamical systems approach with varying initial conditions and inputs provides a mechanisitic understanding of neural population activity underlying a reach decision

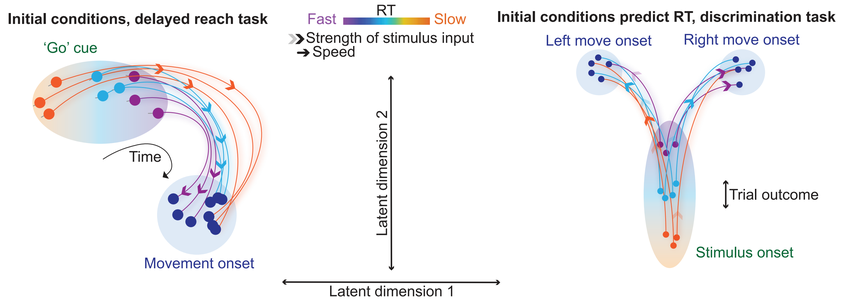
$$dX/dt = F(X) + U$$

*F- recurrent dynamics in region of interest (ROI); U- input to the system outside ROI; $X_O$- Initial condition in ROI*

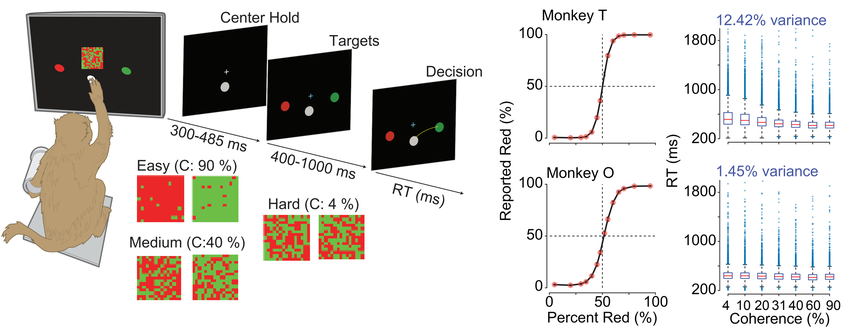
• Prediction 1: the initial condition, as indexed by the prestimulus neural population state, predicts poststimulus decision-related neural dynamics and behavior (i.e., reaction time (RT))

• Prediction 2: the speed of choice-selective dynamics after stimulus onset depends on initial conditions and stimulus strength

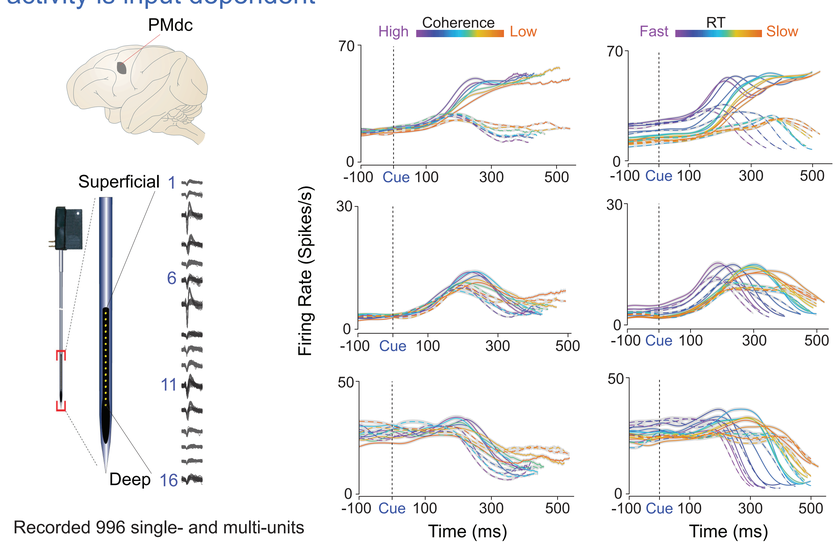
## Hypotheses



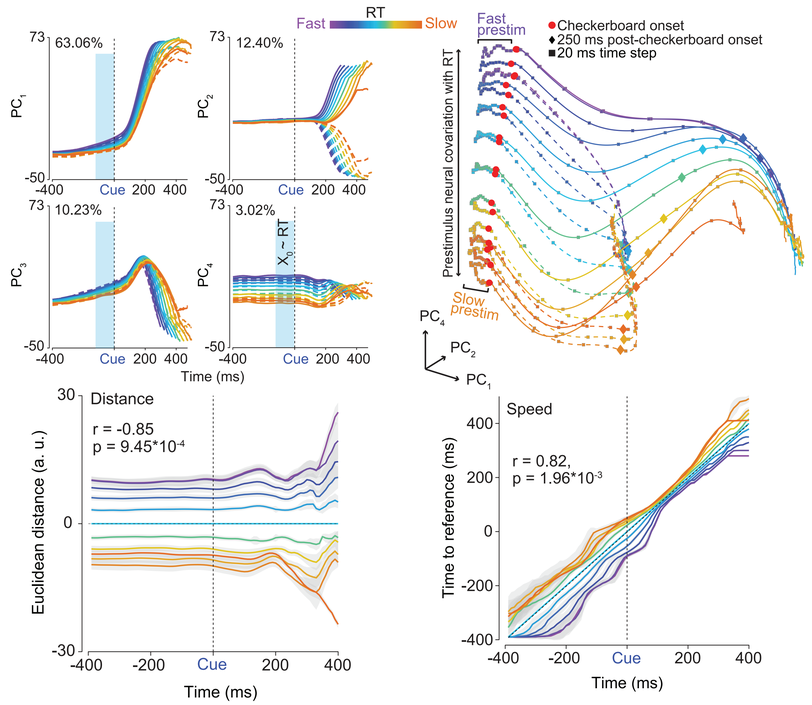

## Decision-making is dependent on sensory evidence and internal state



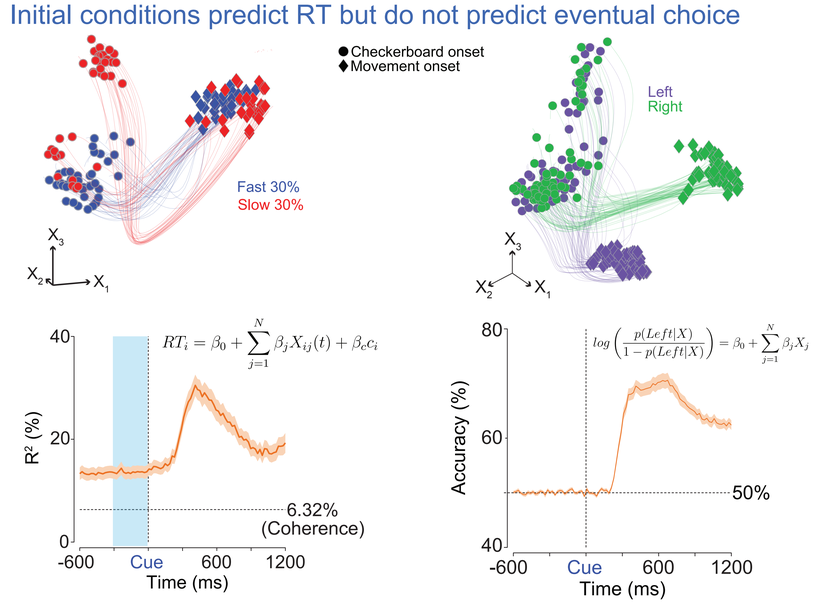

## Single-unit prestimulus firing rates covary with RT and poststimulus activity is input dependent



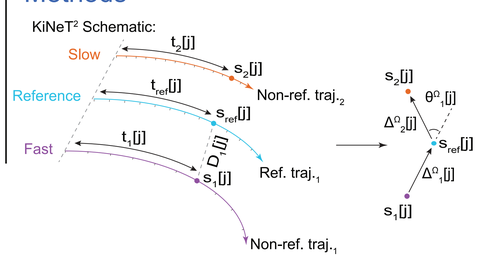

## Position and "velocity" of initial condition correlate with poststimulus dynamics and RT




## Initial conditions predict RT but do not predict eventual choice




## Methods




## Glossary

**$t_{ref}[j]/t_1[j]$** - Time to ref./non-ref. traj. i at jth timepoint

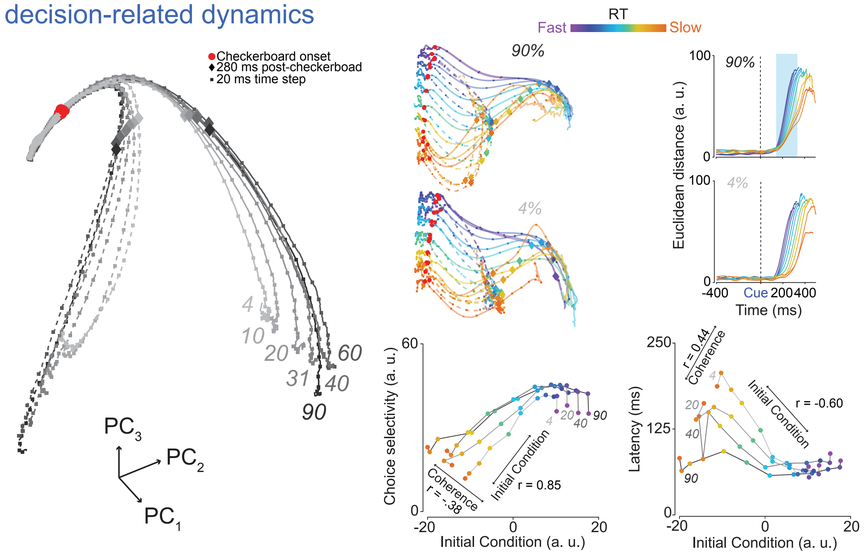
**$s_{ref}[j]/s_1[j]$** - Position of ref./non-ref. traj. i at jth timepoint

**$D_1[j]$** - Dist. b/w nearest pt. on non-ref traj. and ref. traj. at index j

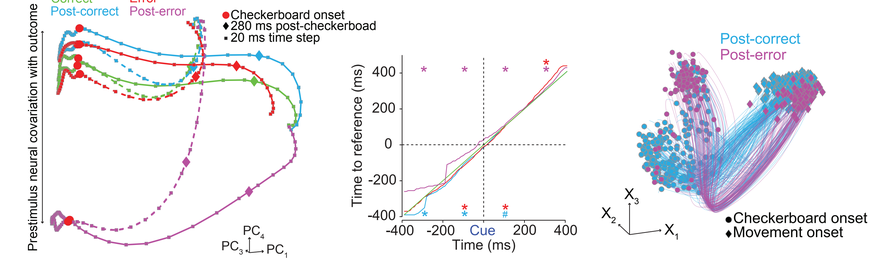
**$\theta^{\Omega}_1[j]$** - Angle b/w two adjacent vectors $\Delta^{\Omega}_1[j]$ and $\Delta^{\Omega}_2[j]$

**$\Delta^{\Omega}_1[j]$** - vector connecting two nearest points on two adjacent trajectories

## Inputs and initial conditions both contribute to the speed of poststimulus decision-related dynamics




## The outcome of the previous trial influences the initial condition




## Conclusions

• Lawful relationships between low-dimensional neural activity and task variables such as choice, RT, stimulus difficulty, and past outcomes

• Initial conditions have as strong or stronger impact, as compared to inputs, in determining timing of decision-related dynamics and behavior

• Bridges previously disparate findings from SAT, PES, and motor planning providing a framework for deriving decision-making models

## References

1. Afshar, A., Santhanam, G., Yu, B. M., Ryu, S. I., Sahani, M., and Shenoy, K. V. (2011). Single-trial neural correlates of arm movement preparation. *Neuron*, 71:555–564.
2. Remington, E. D., Narain, D., Hosseini, E. A., and Jazayeri, M. (2018). Flexible sensorimotor computations through rapid reconfiguration of cortical dynamics. *Neuron*, 98:1005-1019.e5.
3. Pandarinath, C., O'Shea, D. J., Collins, J., Jozefowicz, R., Stavisky, S. D., Kao, J. C., Trautmann, E. M., Kaufman, M. T., Ryu, S. I., Hochberg, L. R., Henderson, J. M., Shenoy, K. V., Abott, L. F., and Sussillo, D. (2018). Inferring single-trial neural population dynamics using sequential auto-encoders. *Nature Methods*, 15:805-815.

## Acknowledgements

NIH National Institutes of Health
BRAIN & BEHAVIOR RESEARCH FOUNDATION Awarding NARSAD Grants
DARPA
hhmi
Office of Naval Research Science & Technology
Wu Tsai Neurosciences Institute Stanford University
WHITEHALL FOUNDATION 85th ANNIVERSARY 1937 - 2022
SIMONS FOUNDATION