



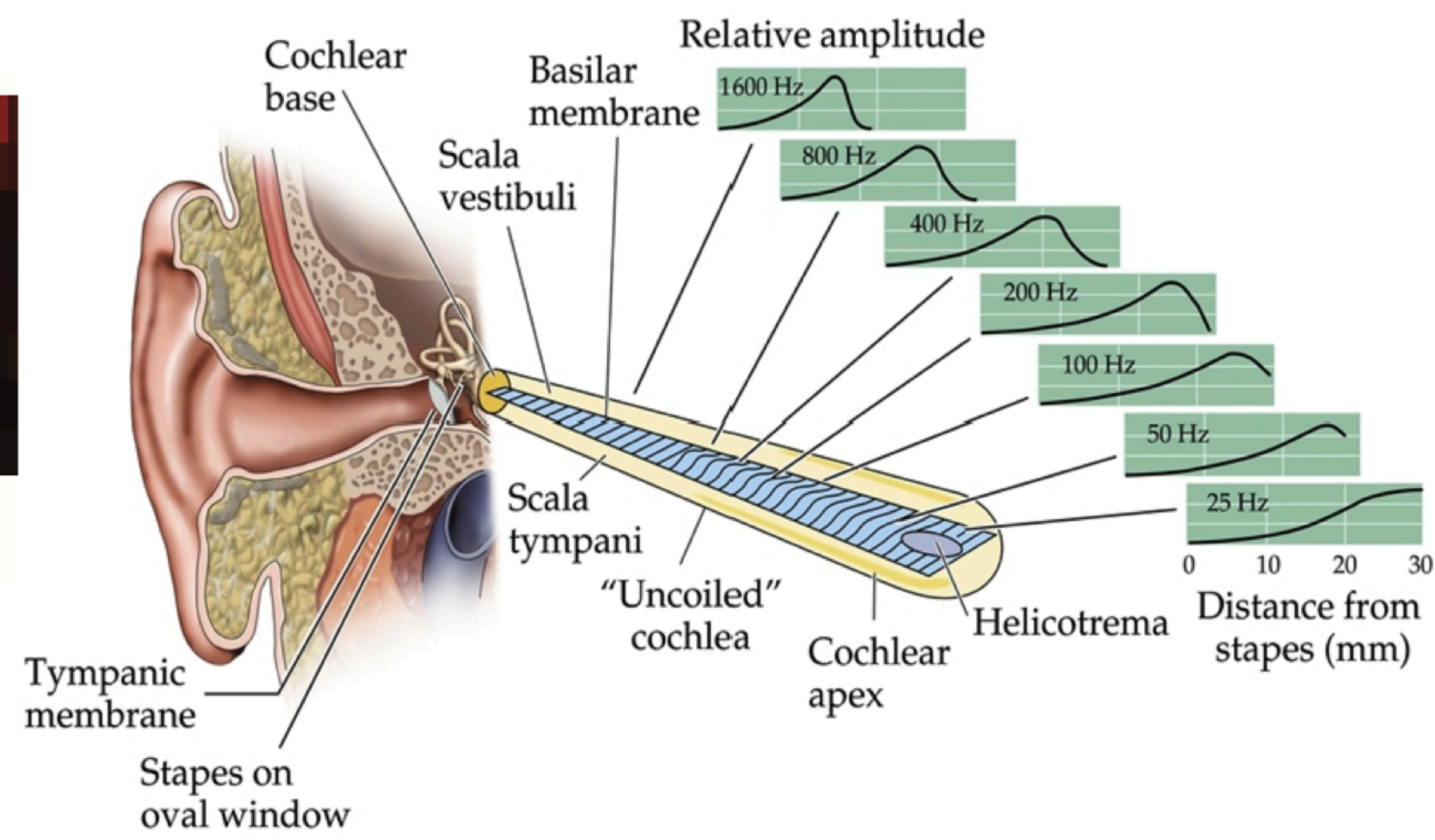
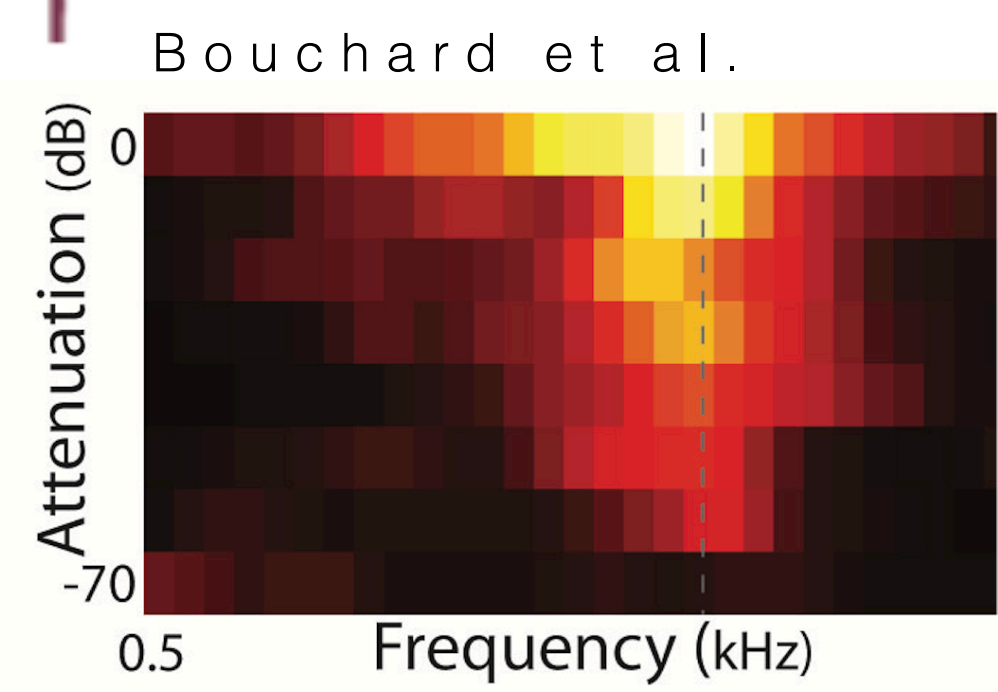
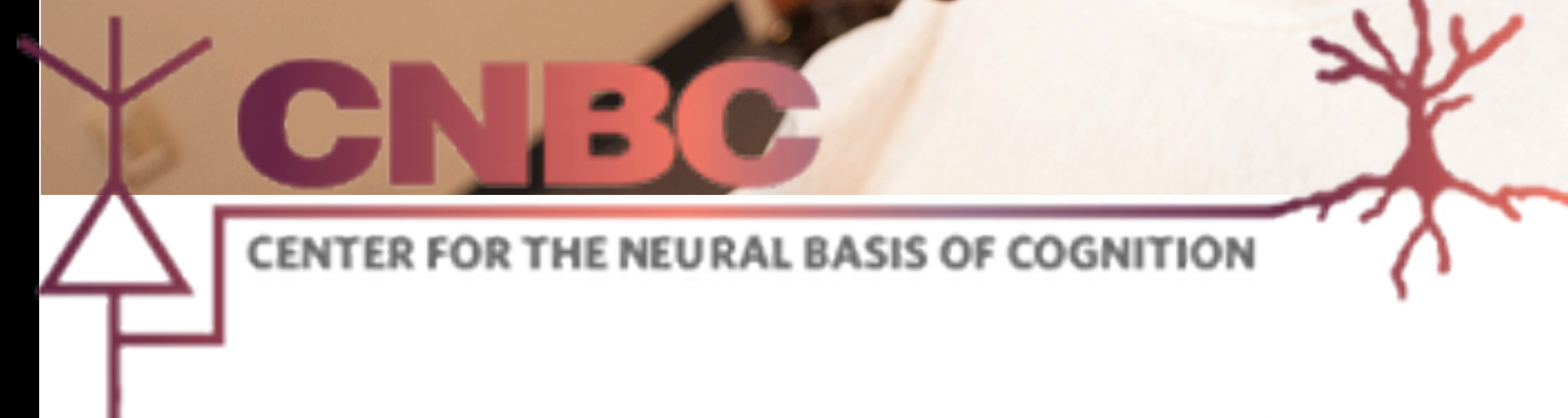
**RELATING VISUAL WORKING MEMORY COMPUTATIONS
TO NETWORK ARCHITECTURE
IN THE BRAIN**

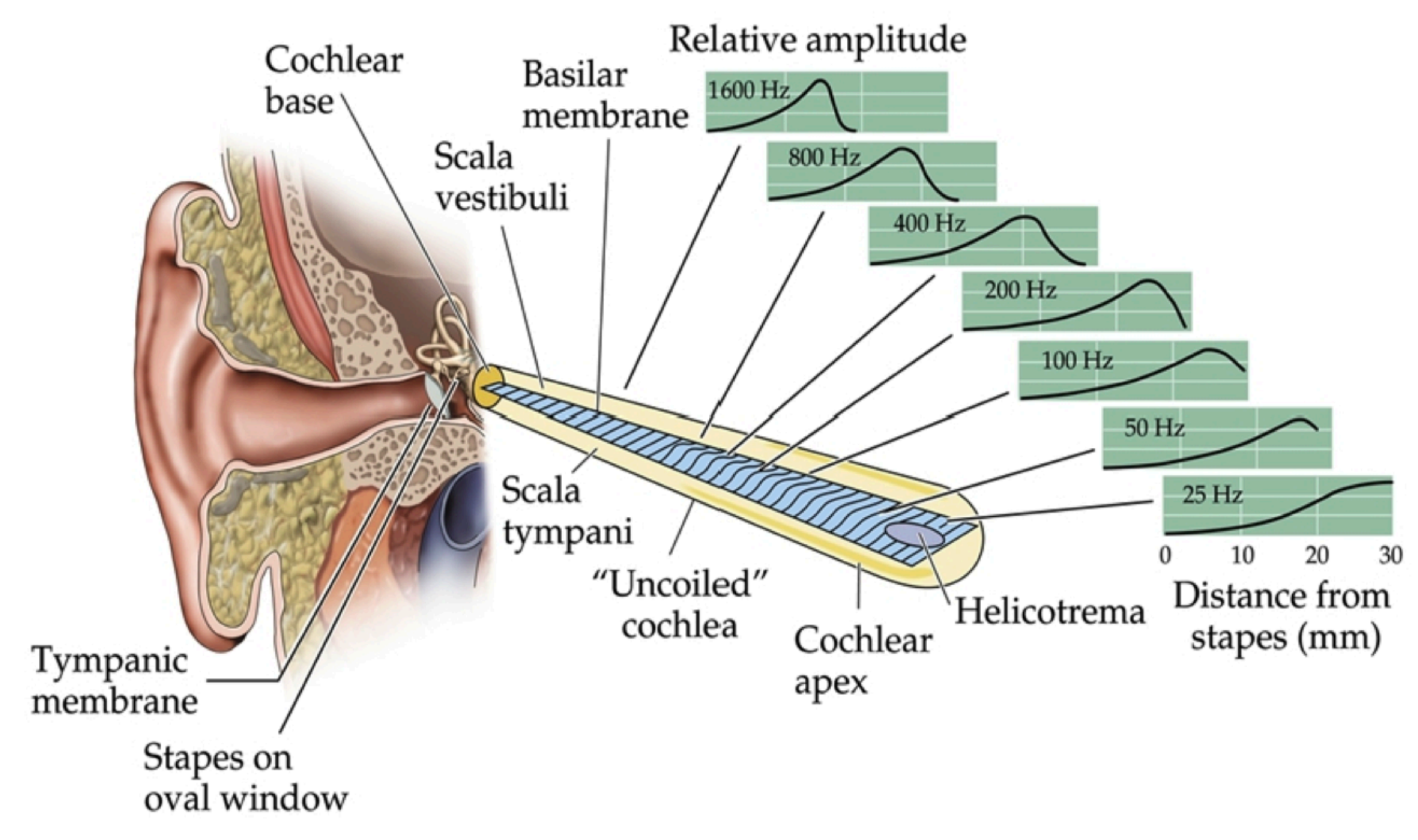
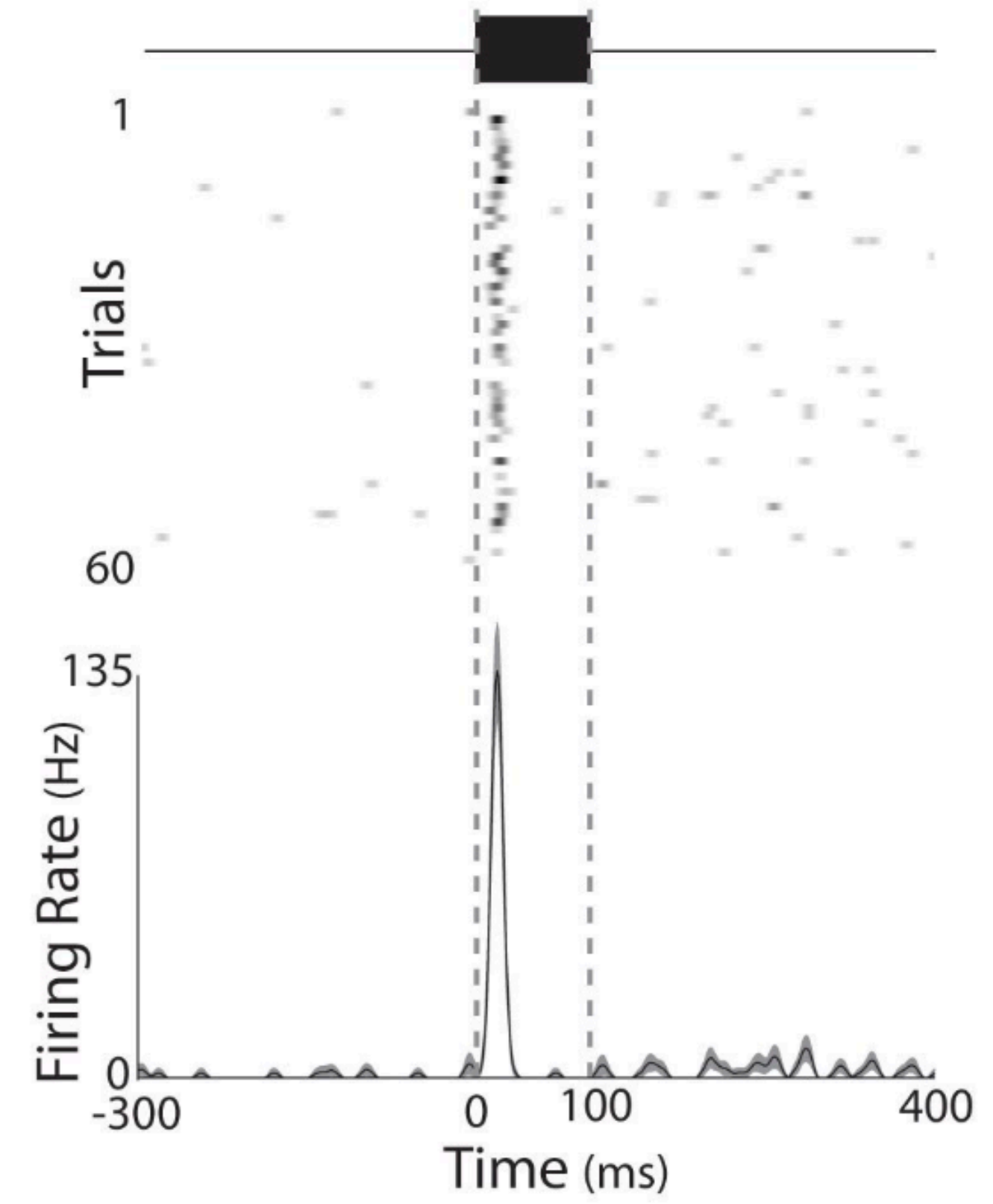
DANIELLE RAGER

SANJEEV KHANNA MATTHEW SMITH, BRENT DOIRON



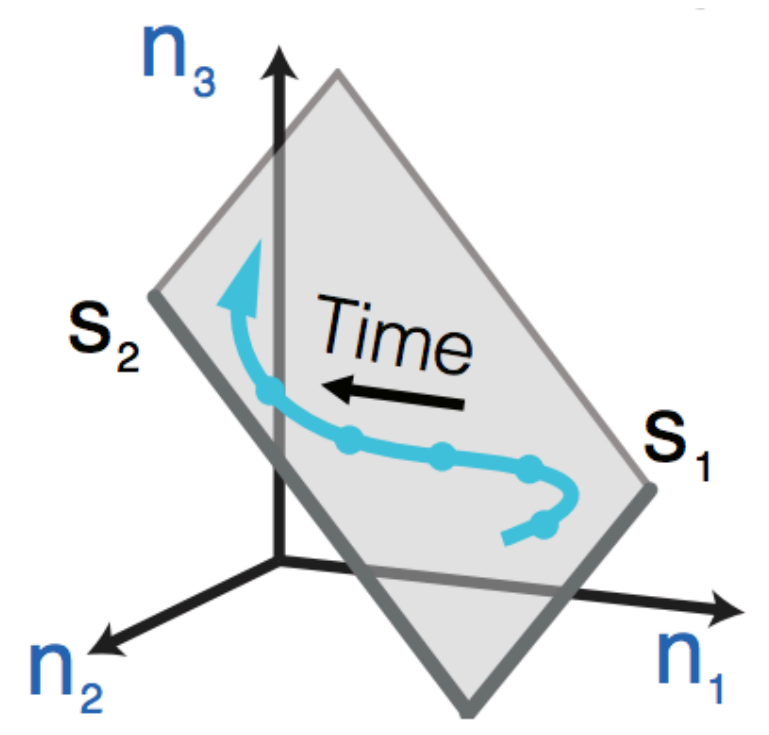
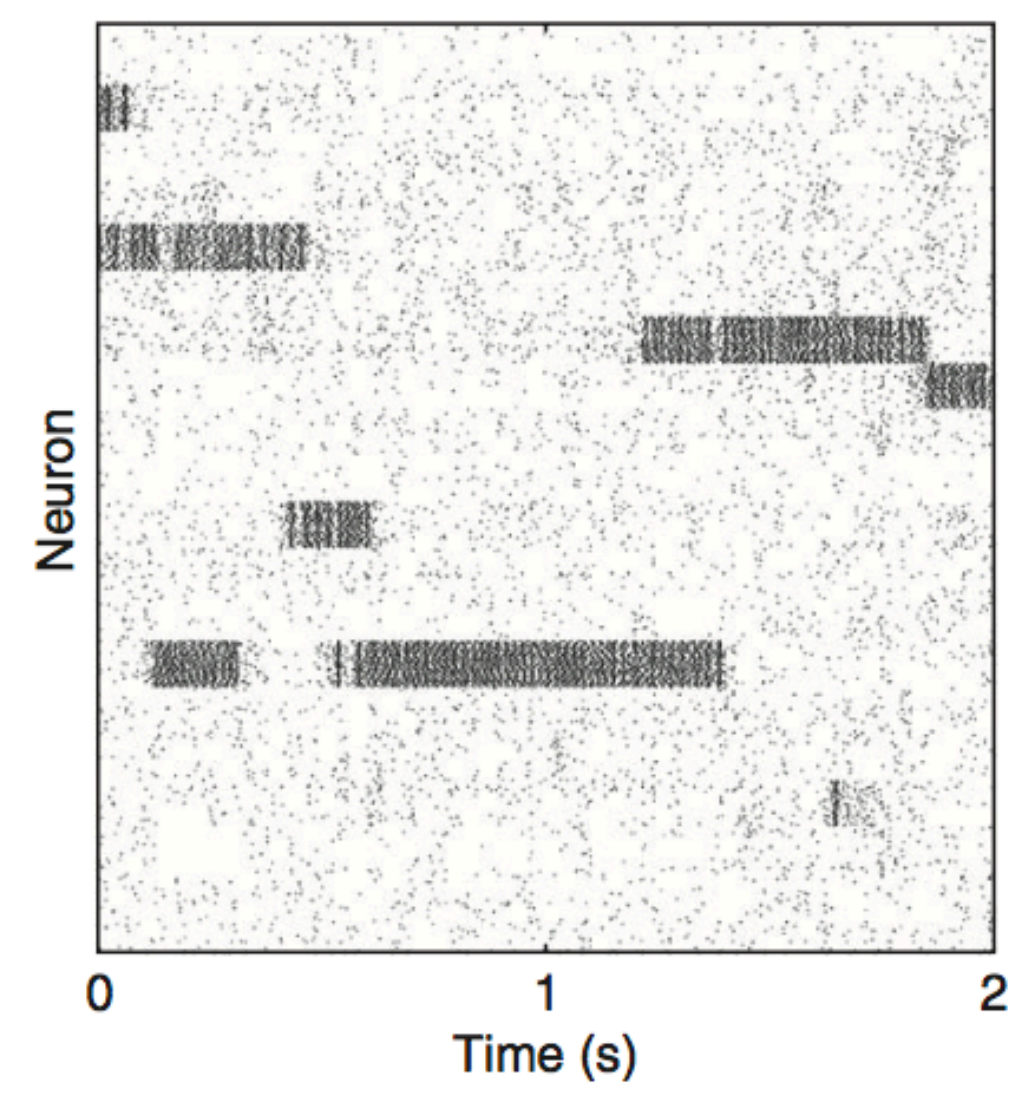
We're trying to understand the **computations** that underlie **sensorimotor behaviors**



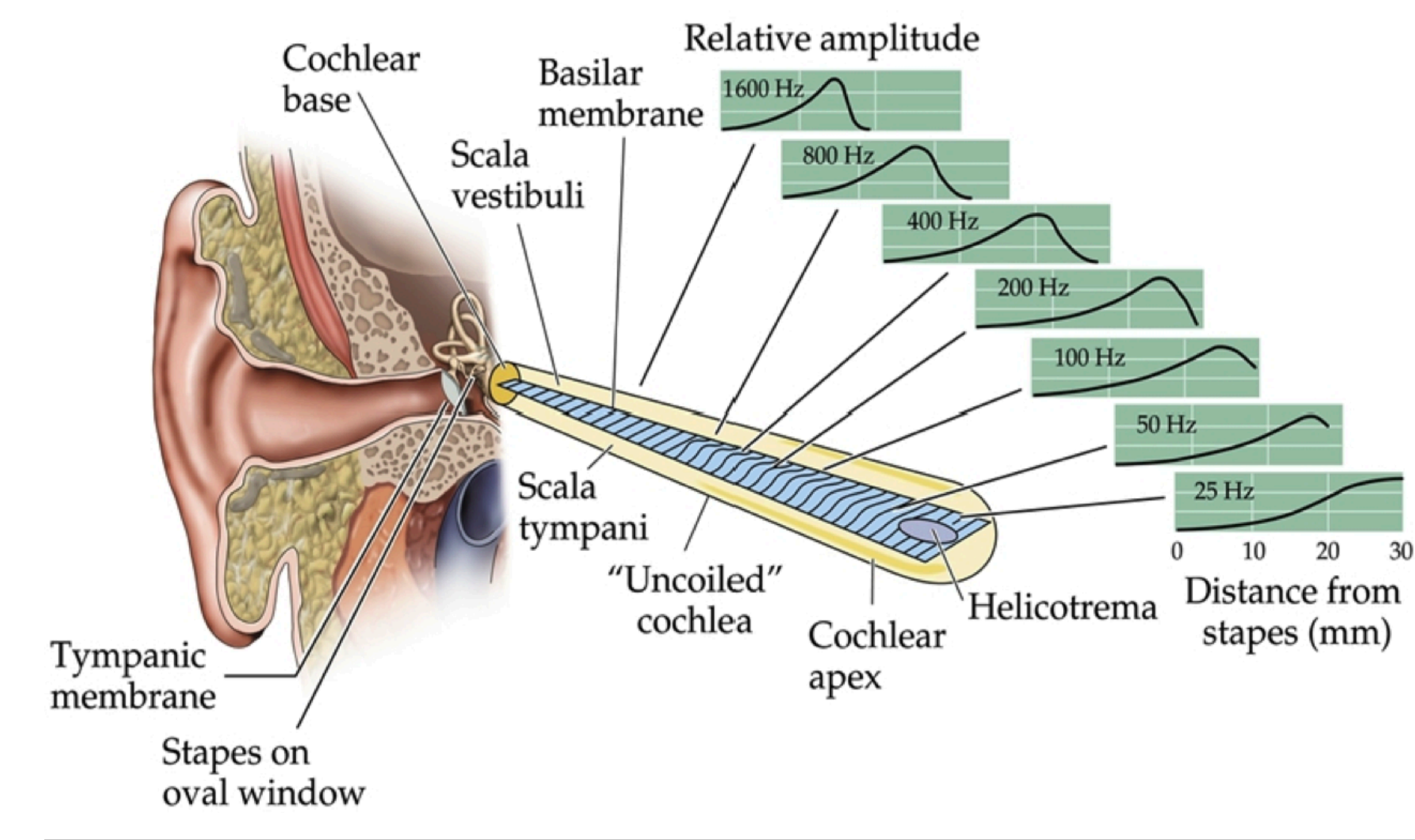


FIRING RESPONSE

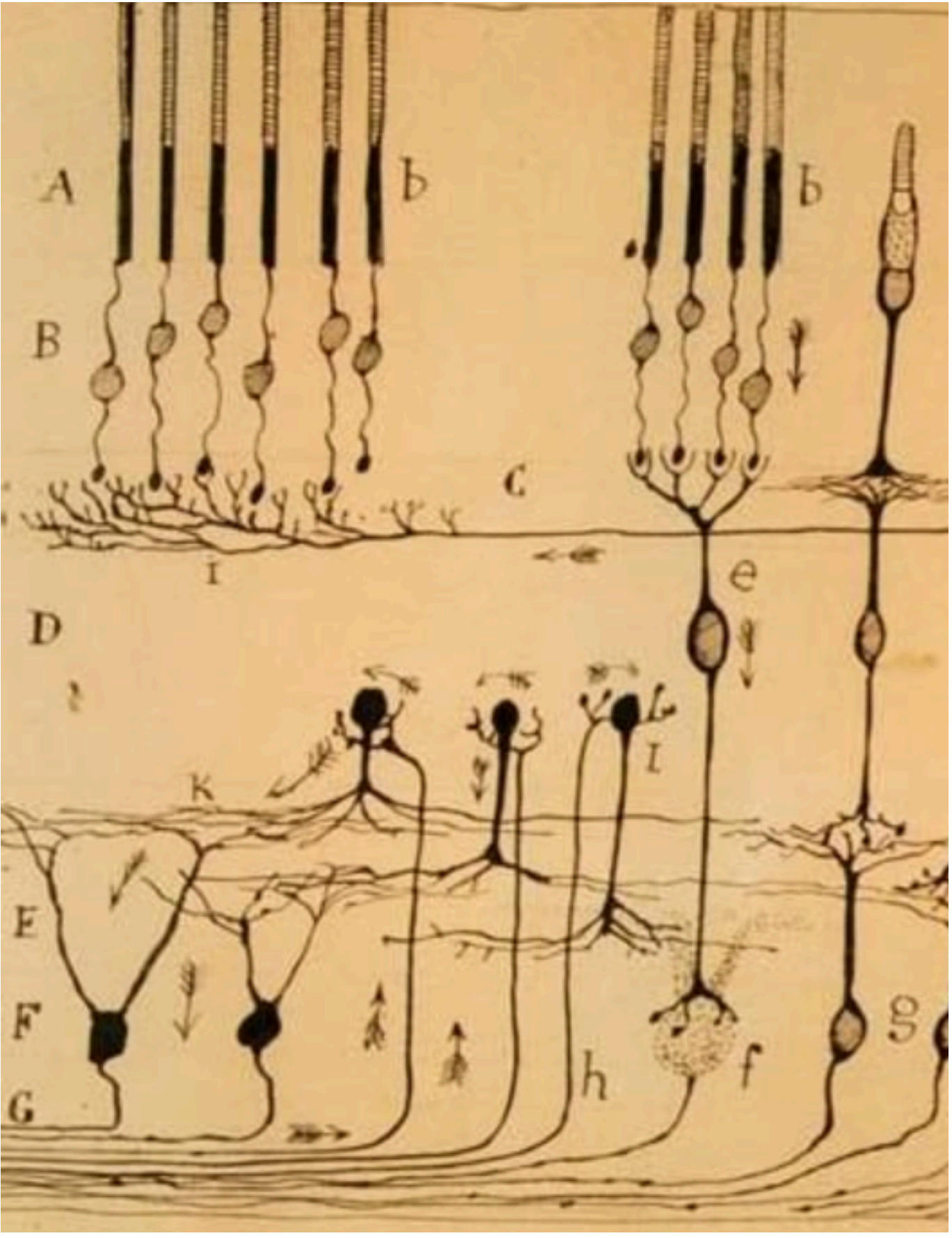
BEHAVIOR /
SENSORIMOTOR COMPUTATION



POPULATION DYNAMICS

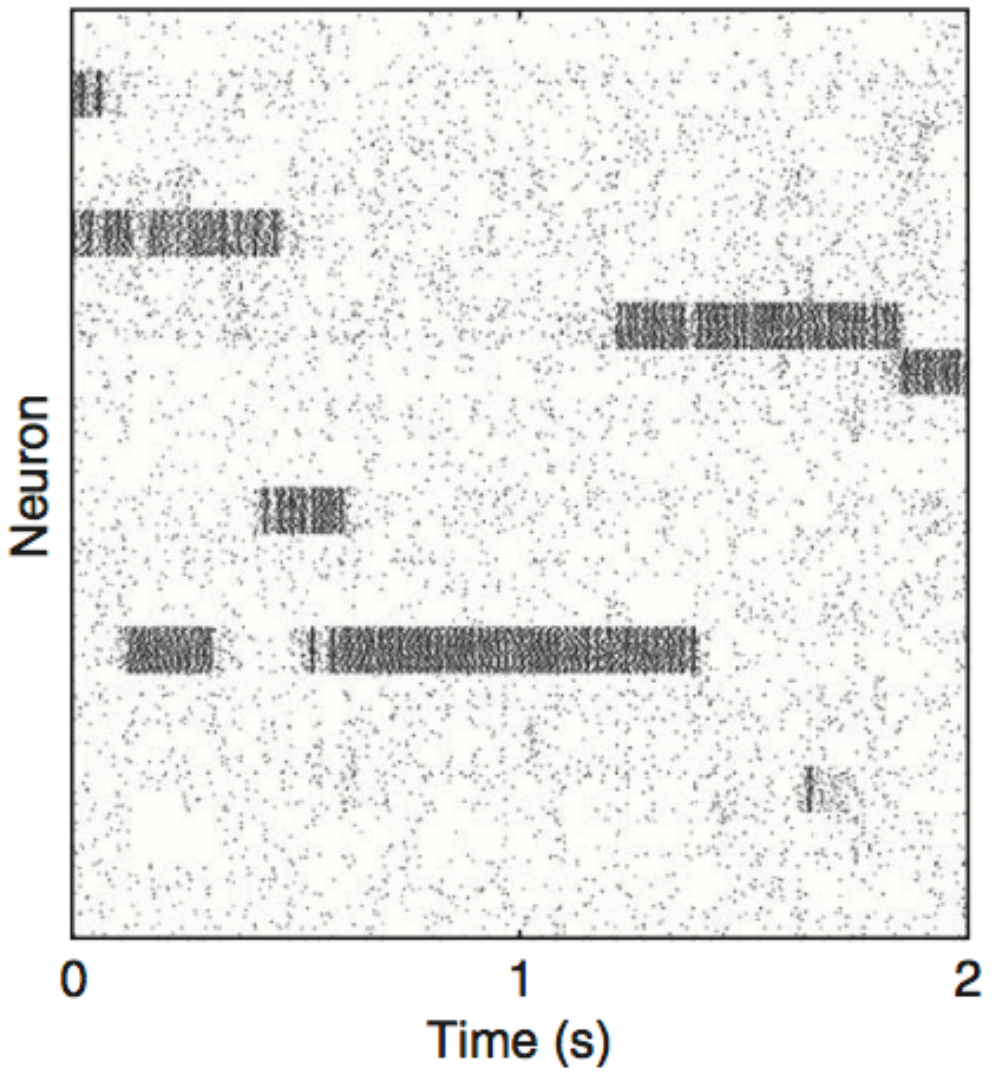


**BEHAVIOR /
SENSORIMOTOR COMPUTATION**

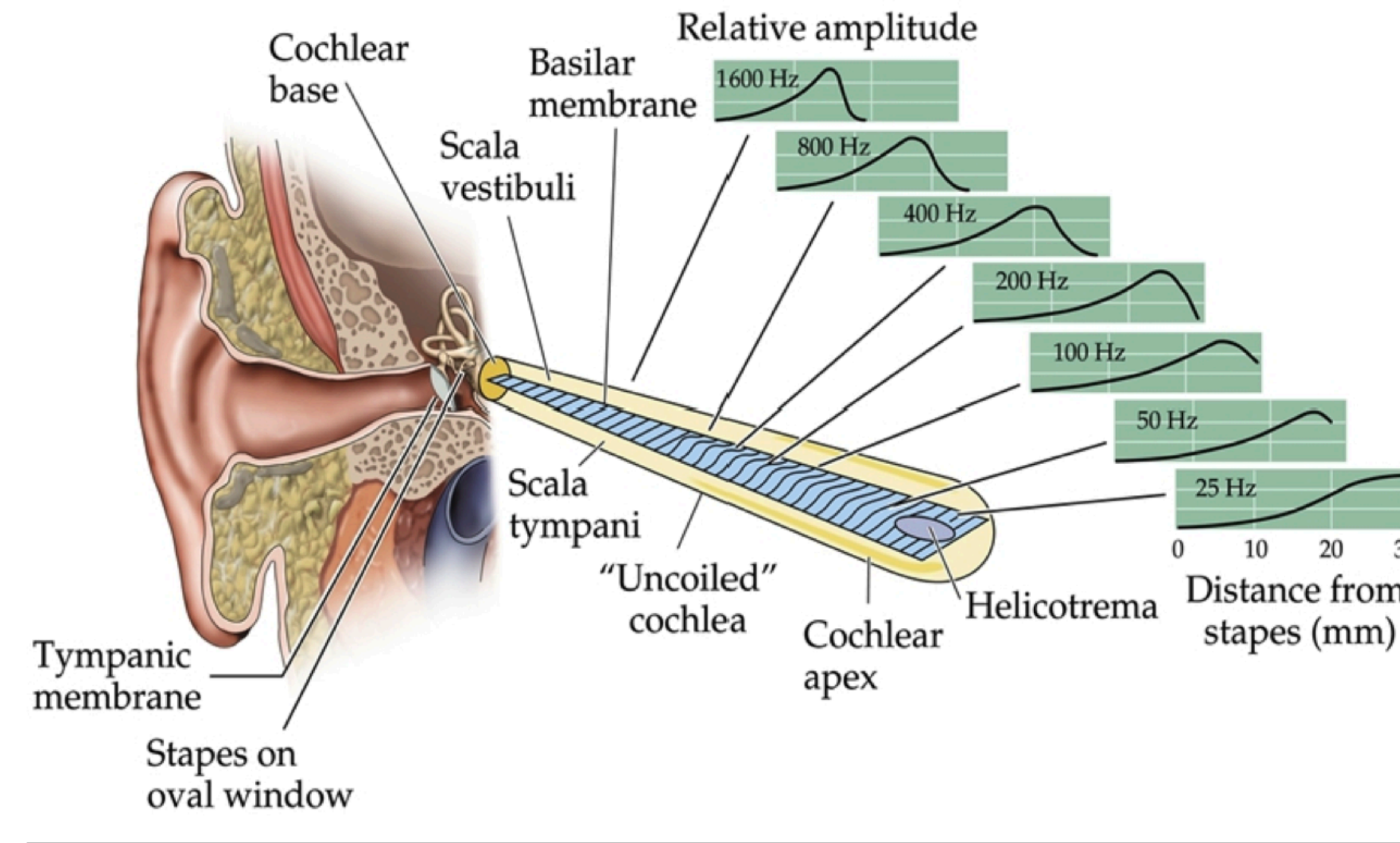
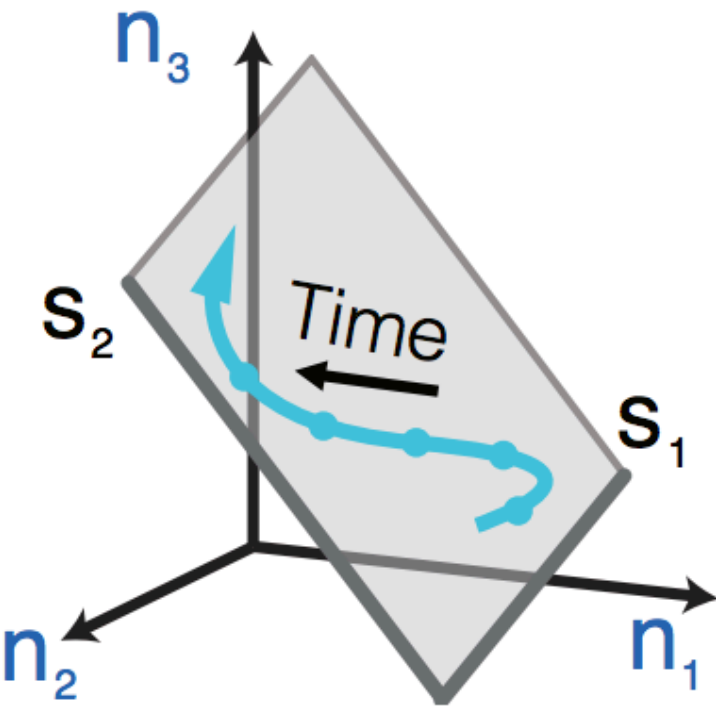


C A J A L , 1 8 5 2 - 1 9 3 4

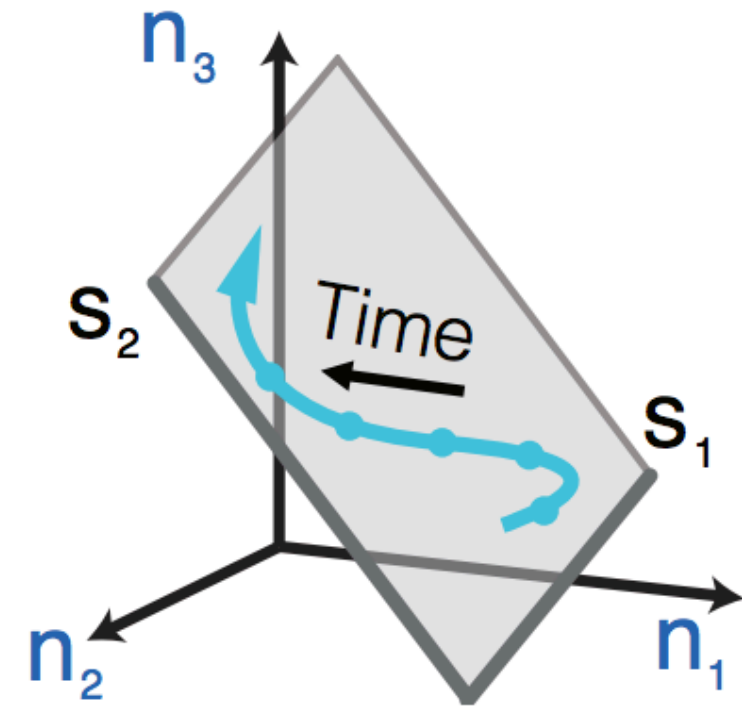
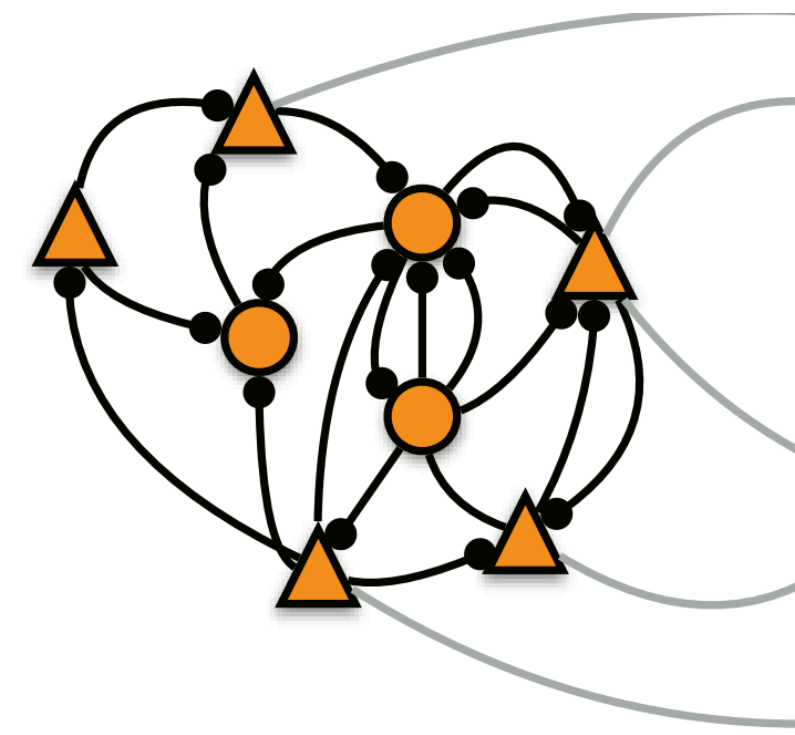
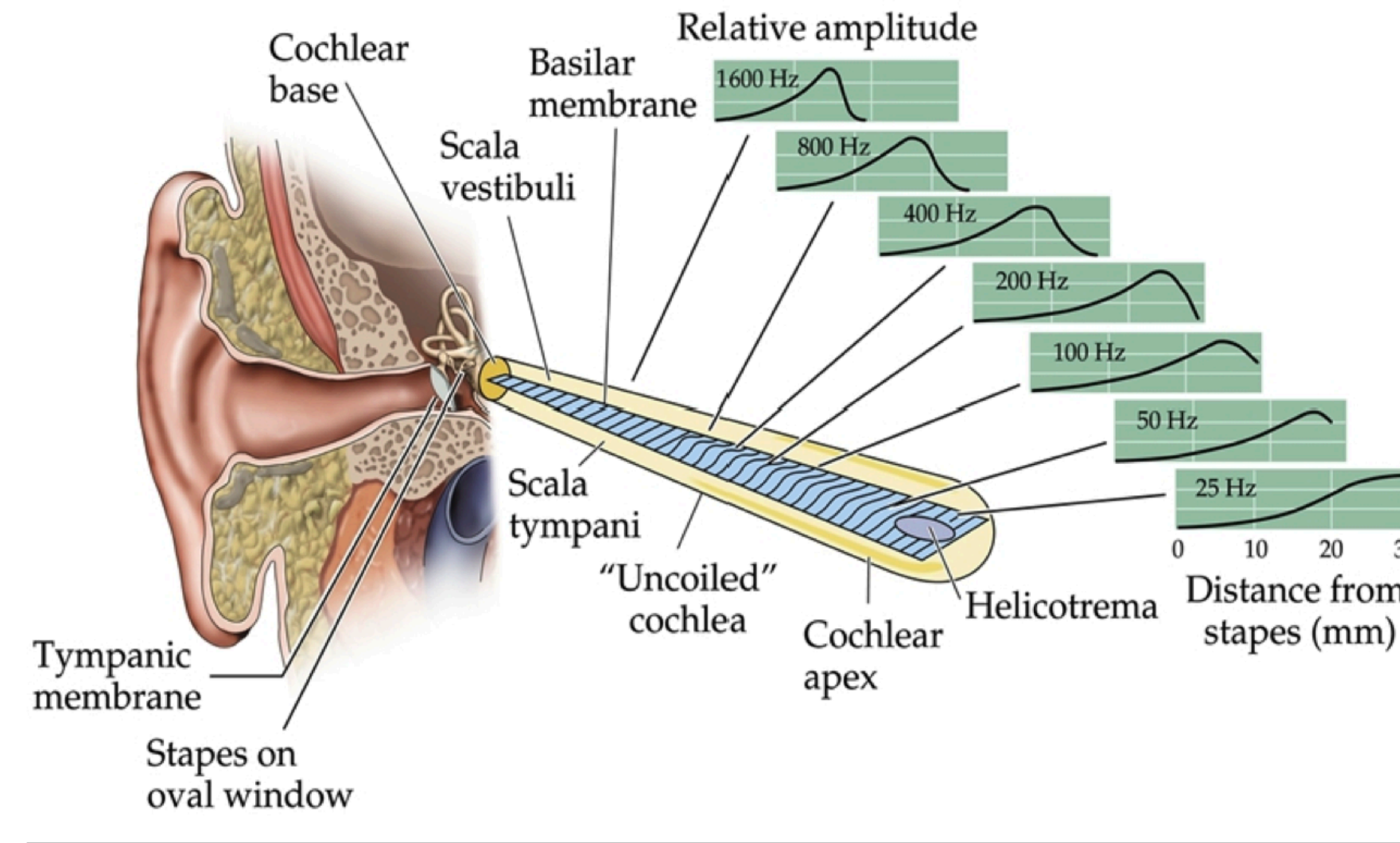
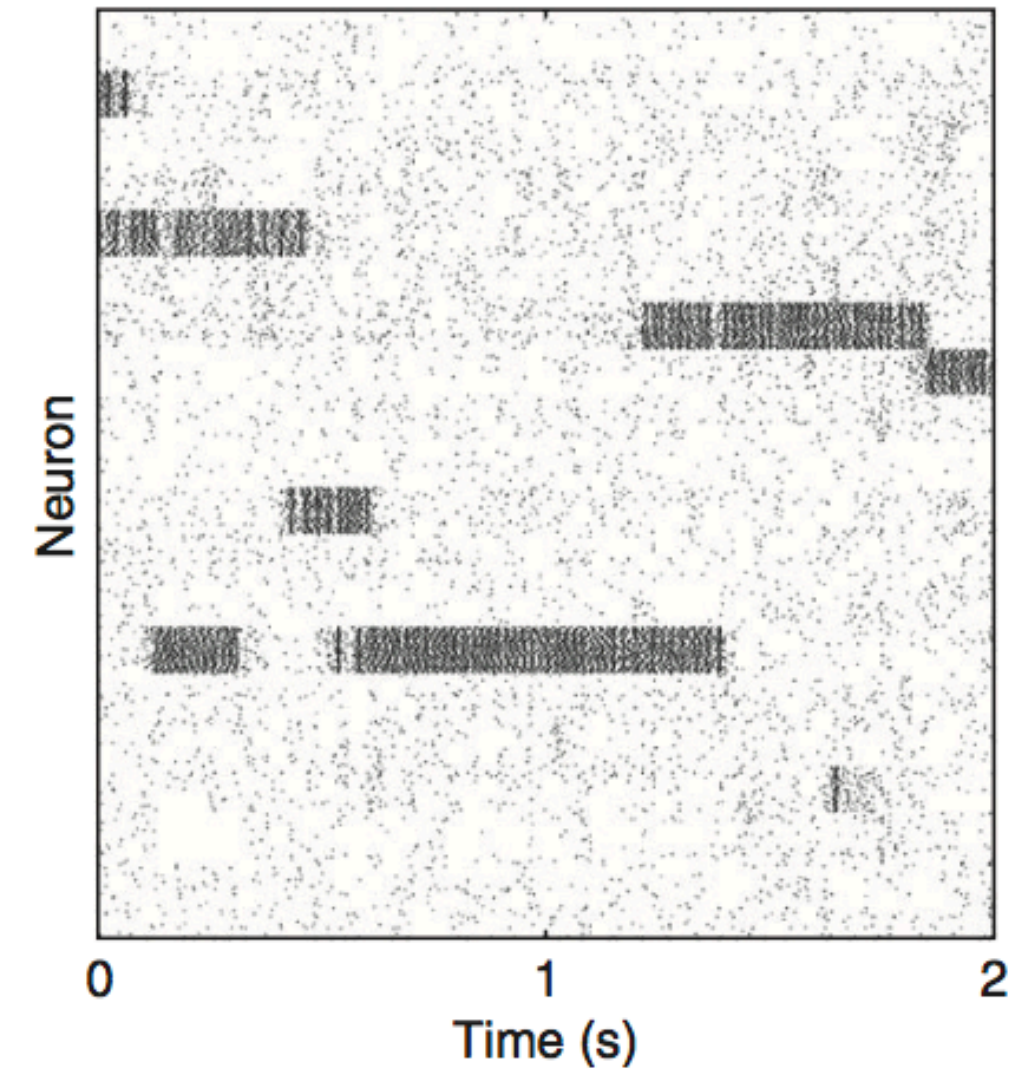
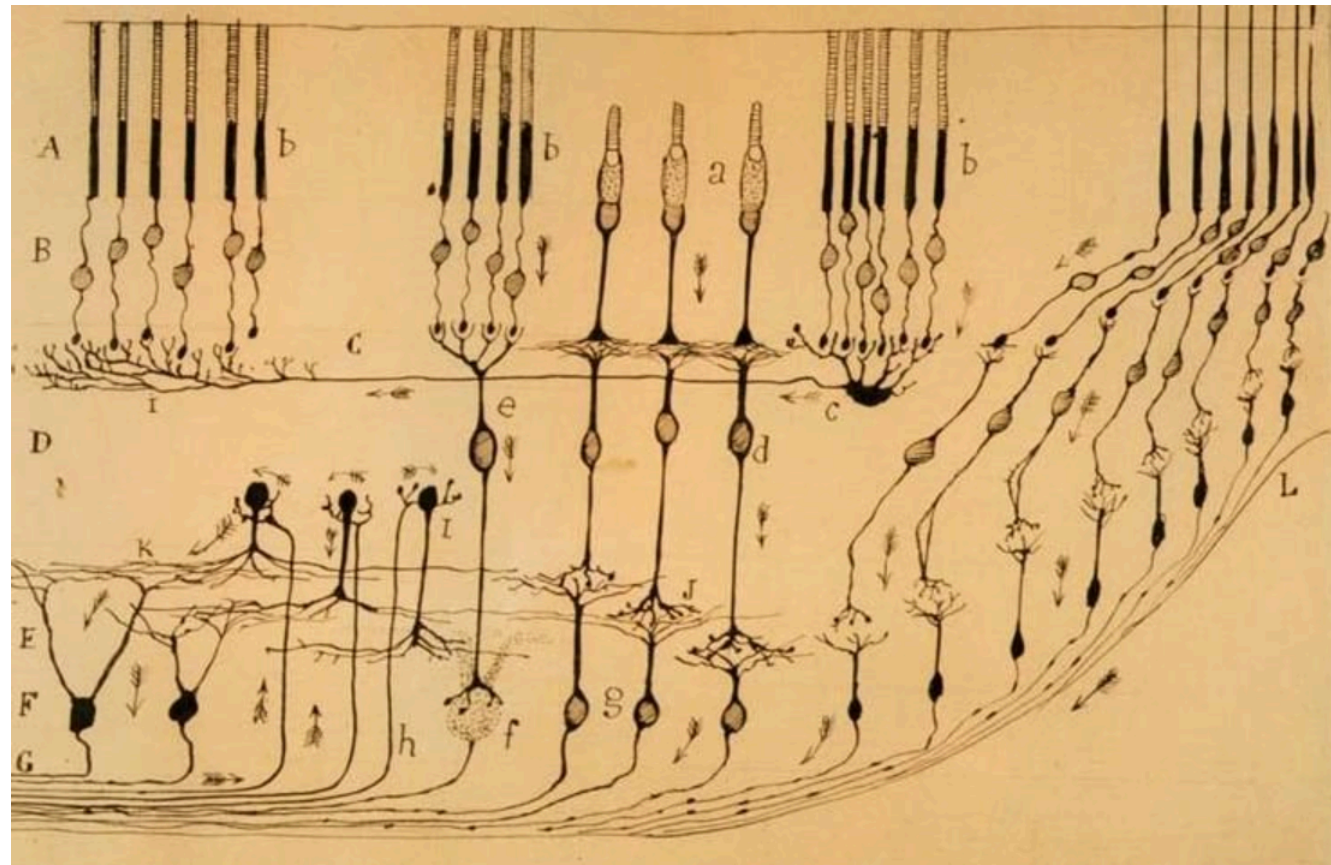
CELLULAR CIRCUIT



POPULATION DYNAMICS



BEHAVIOR /
SENSORIMOTOR COMPUTATION



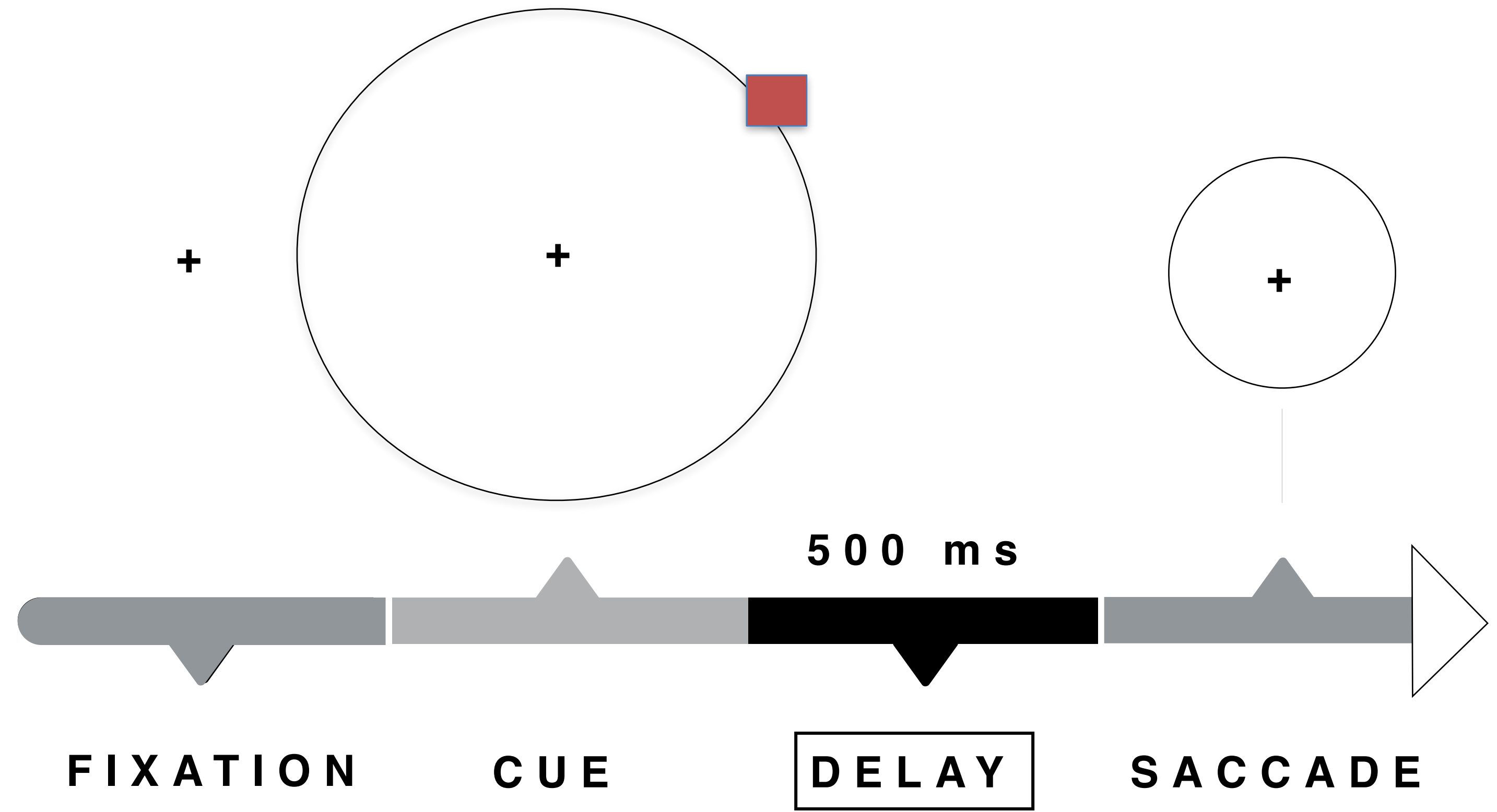
NETWORK MODEL

POPULATION DYNAMICS

**BEHAVIOR /
SENSORIMOTOR COMPUTATION**

BEHAVIOR /
SENSORIMOTOR COMPUTATION

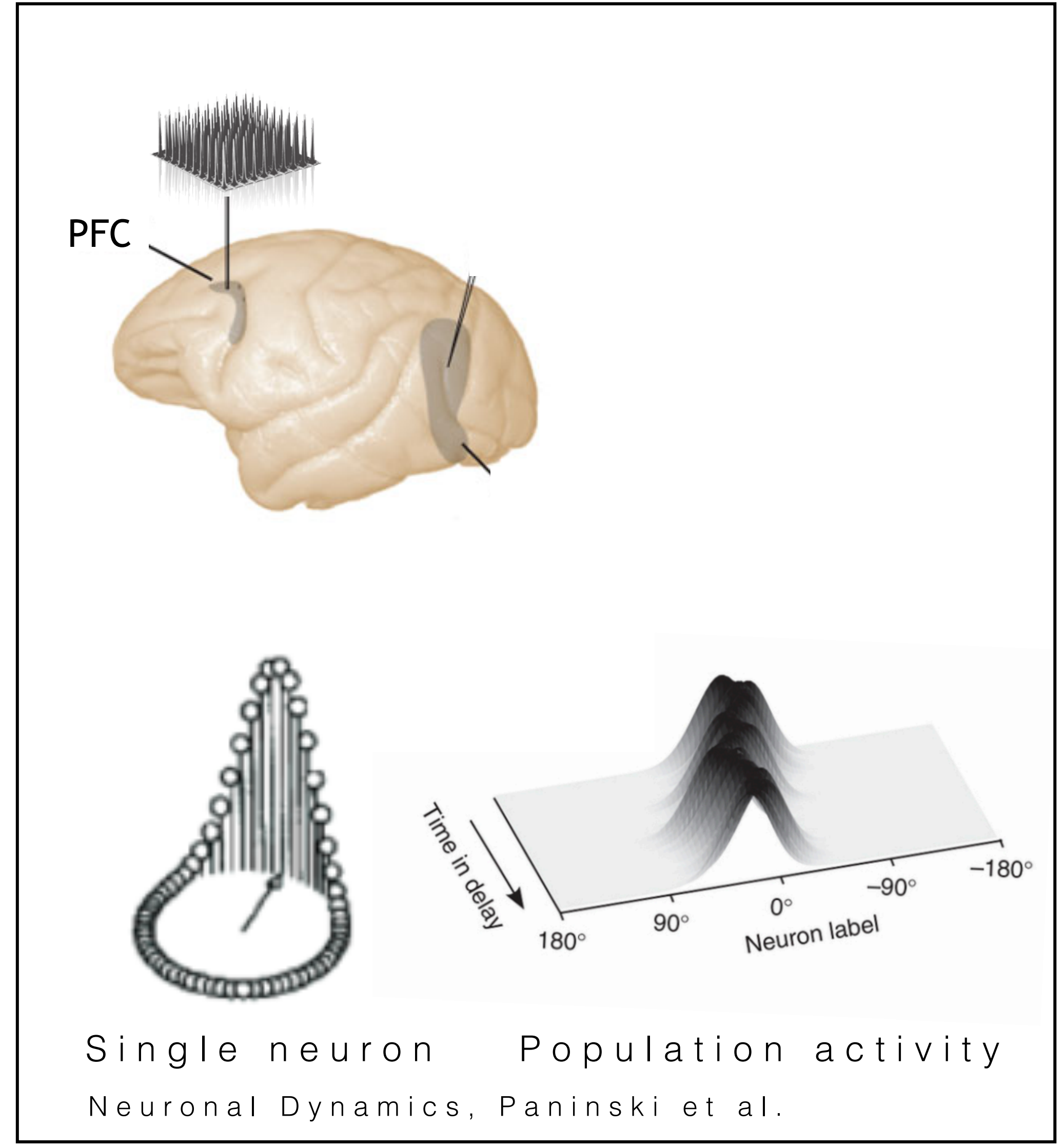
Spatial working memory task



0 ms

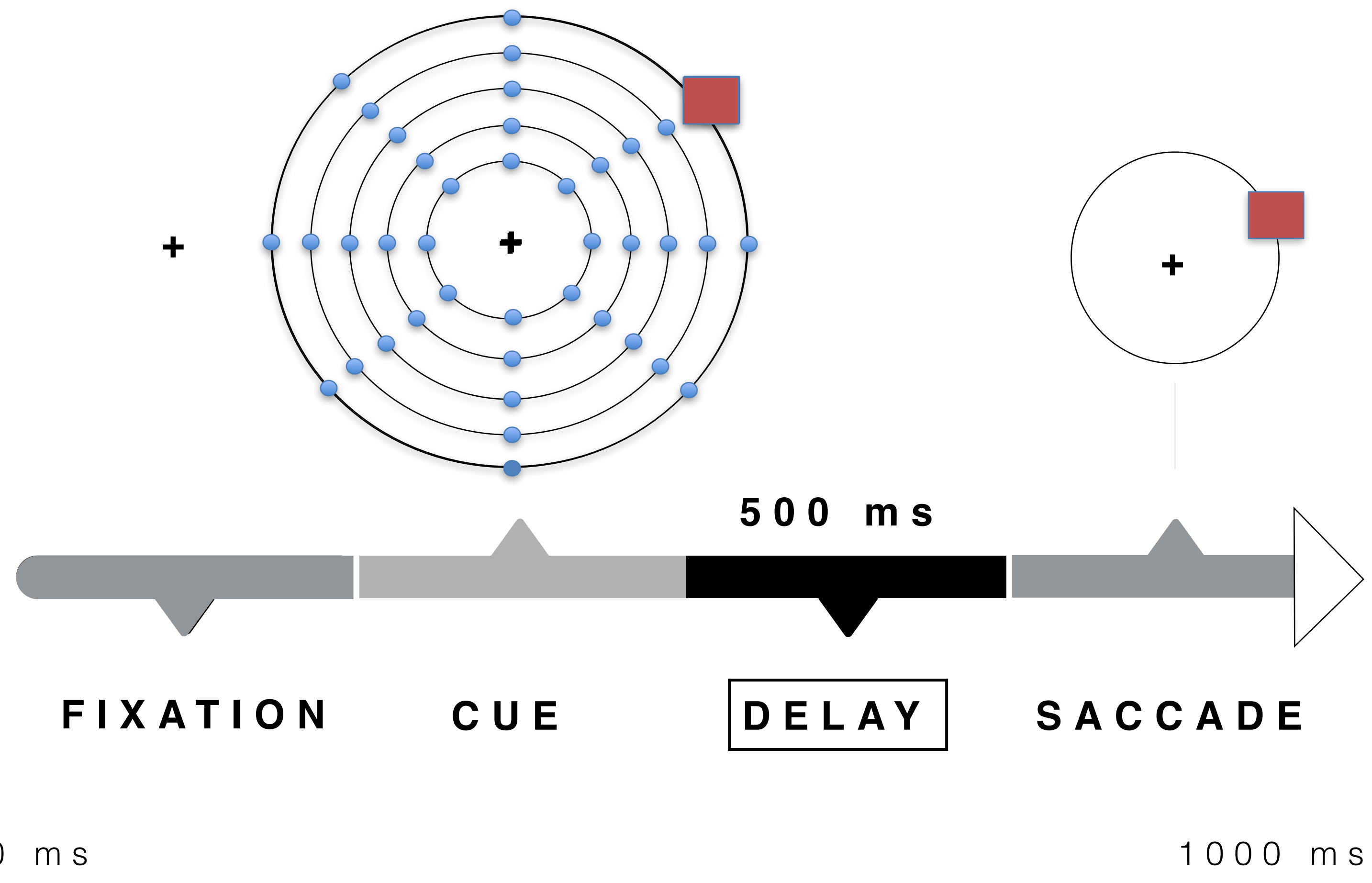
1000 ms

DELAY

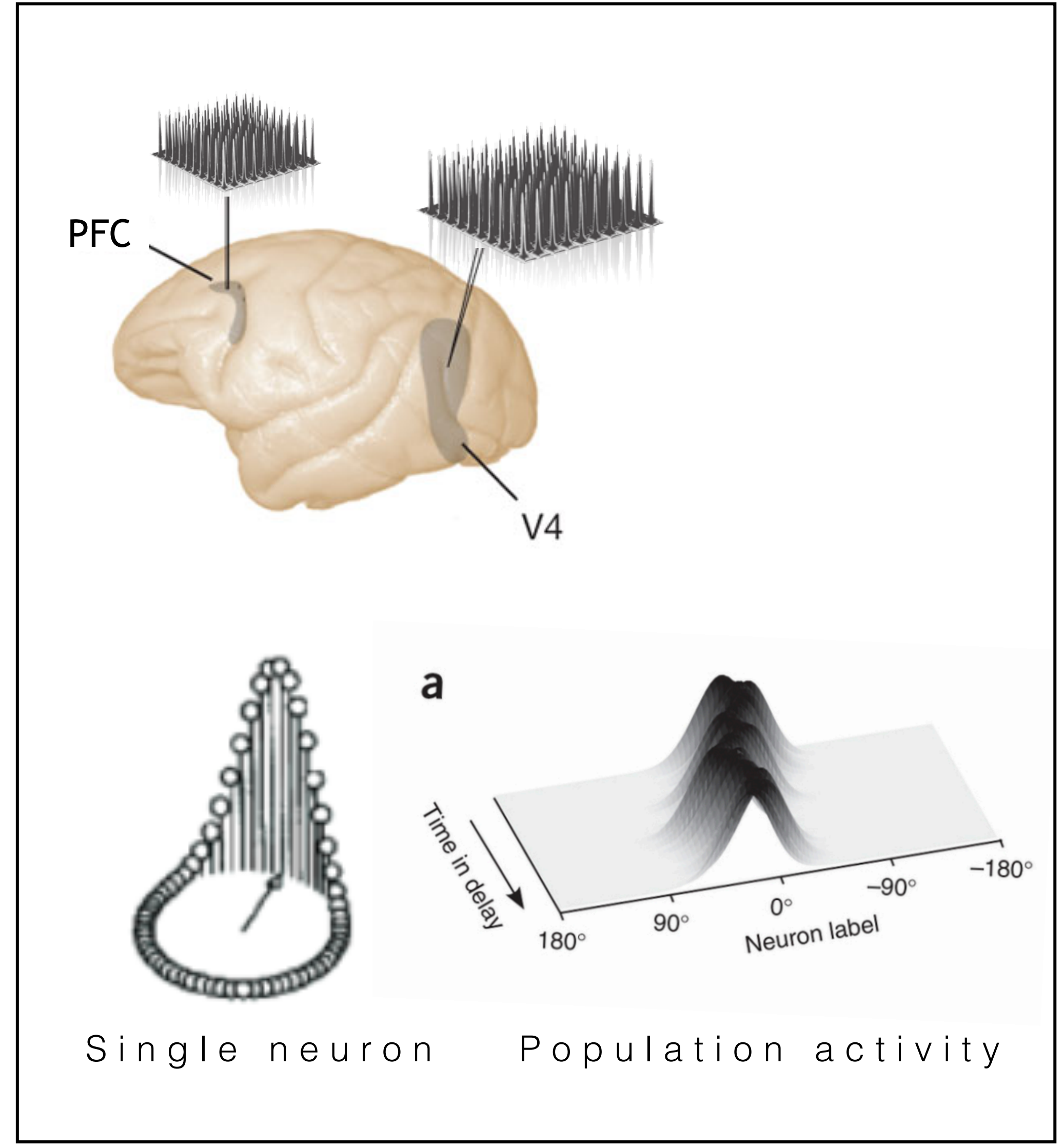


BEHAVIOR /
SENSORIMOTOR COMPUTATION

*Spatial working memory task:
2D space, V4 + PFC recordings*

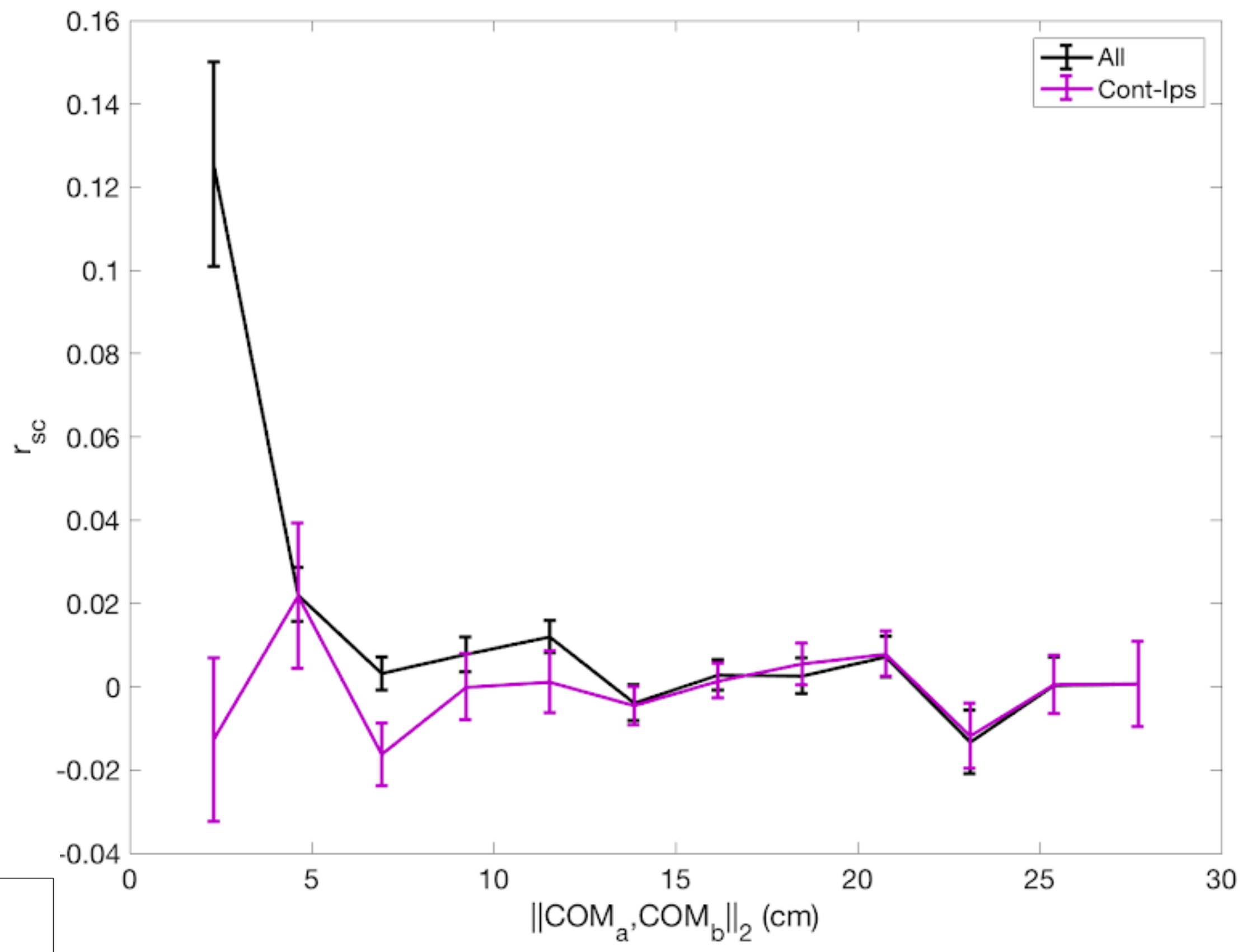
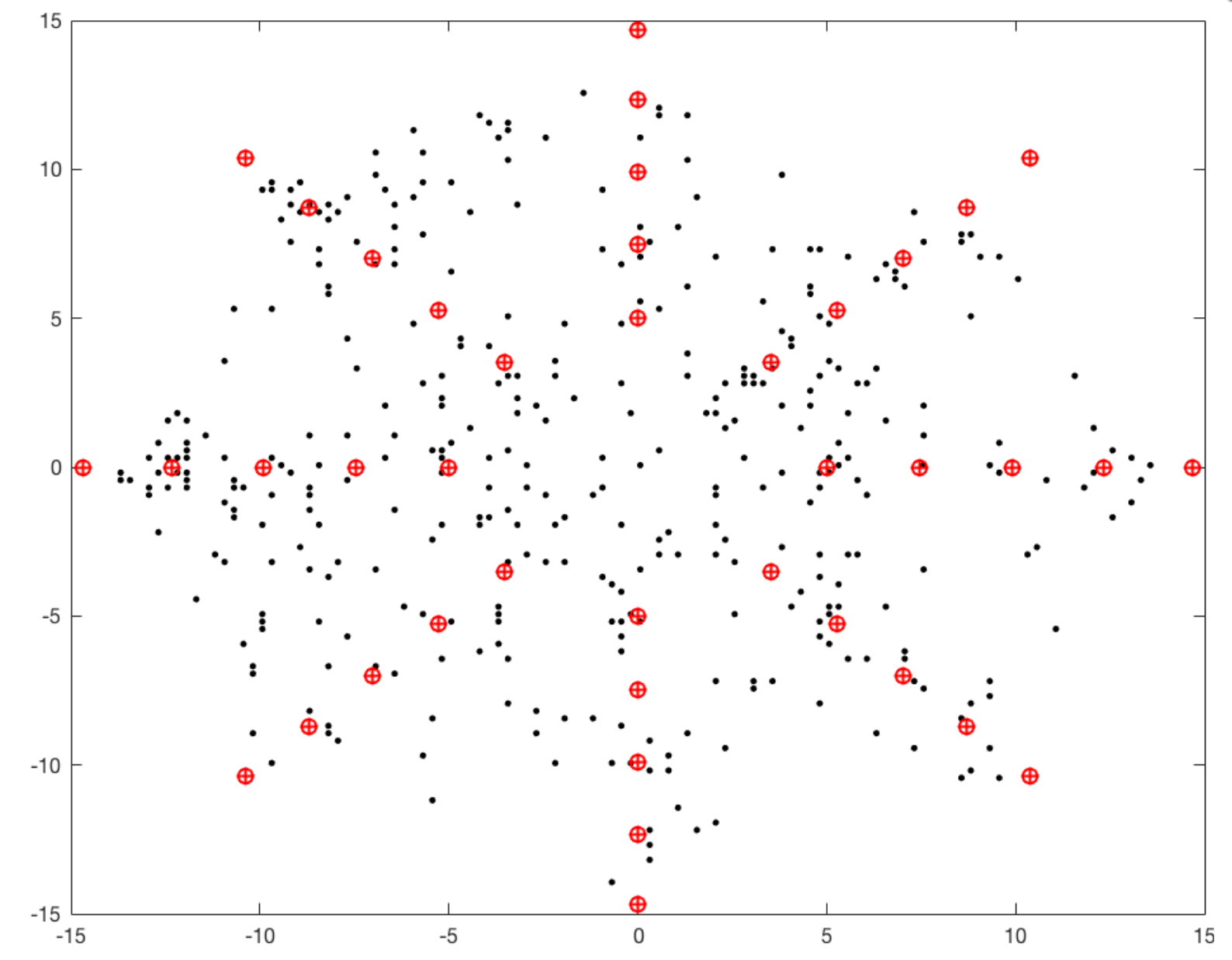
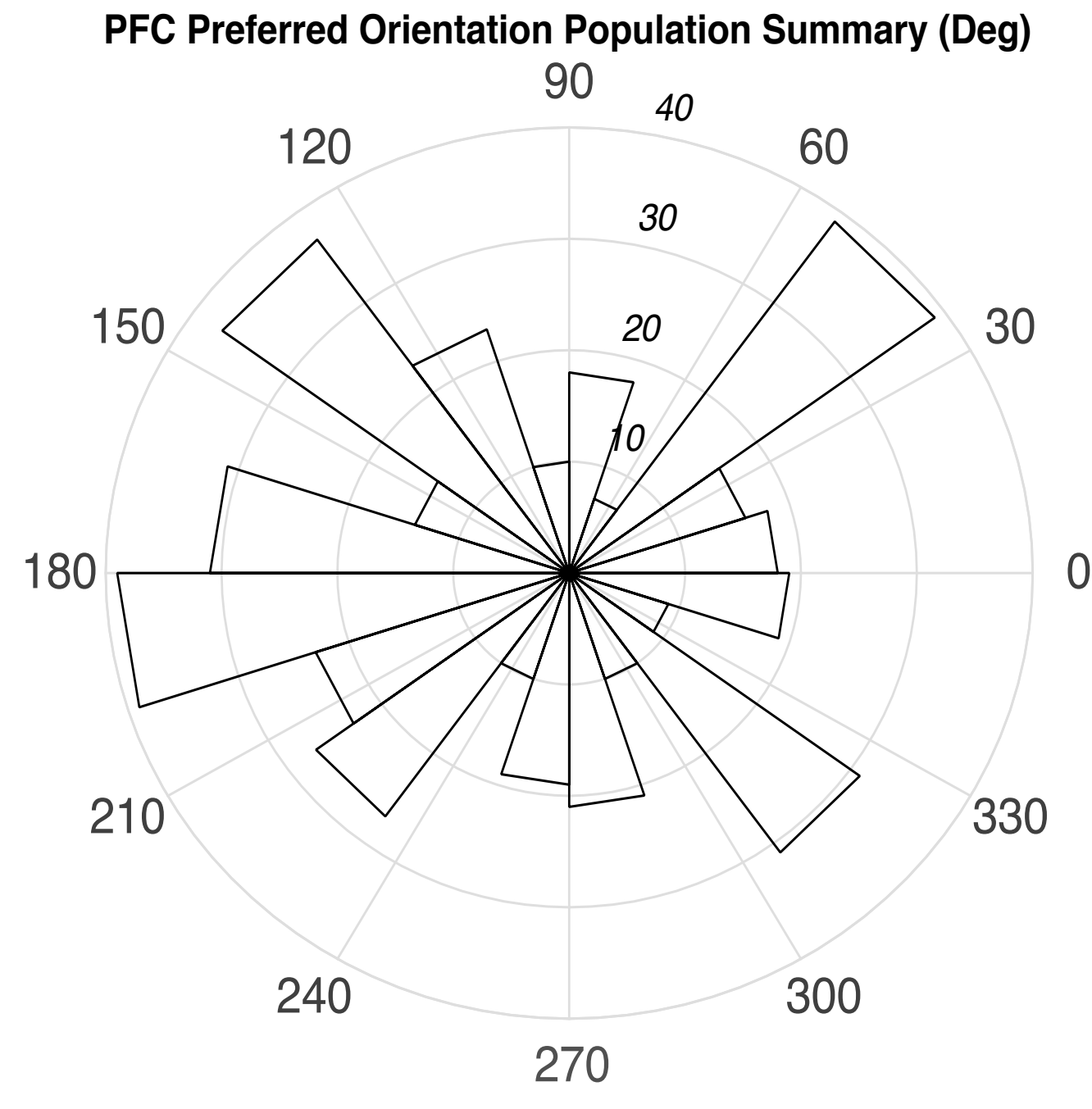
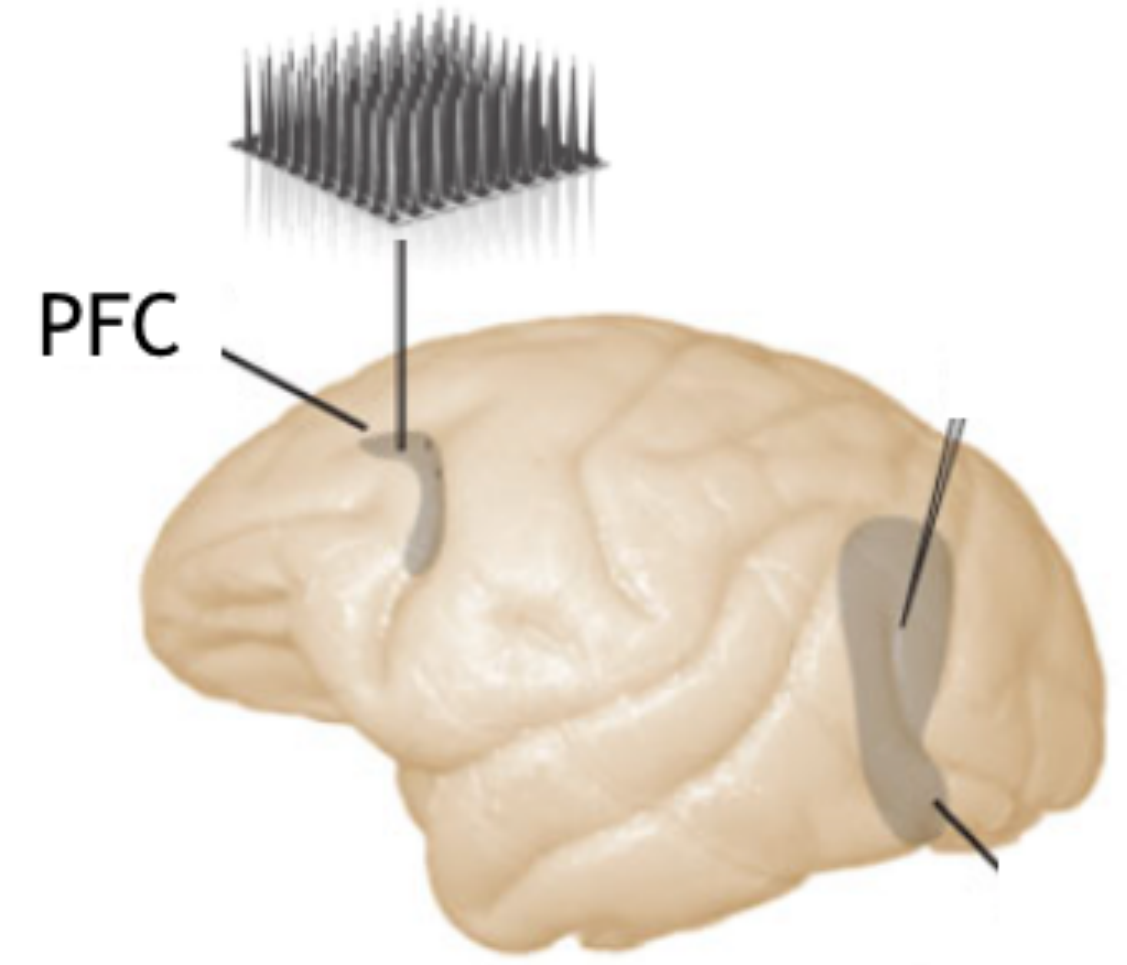


DELAY



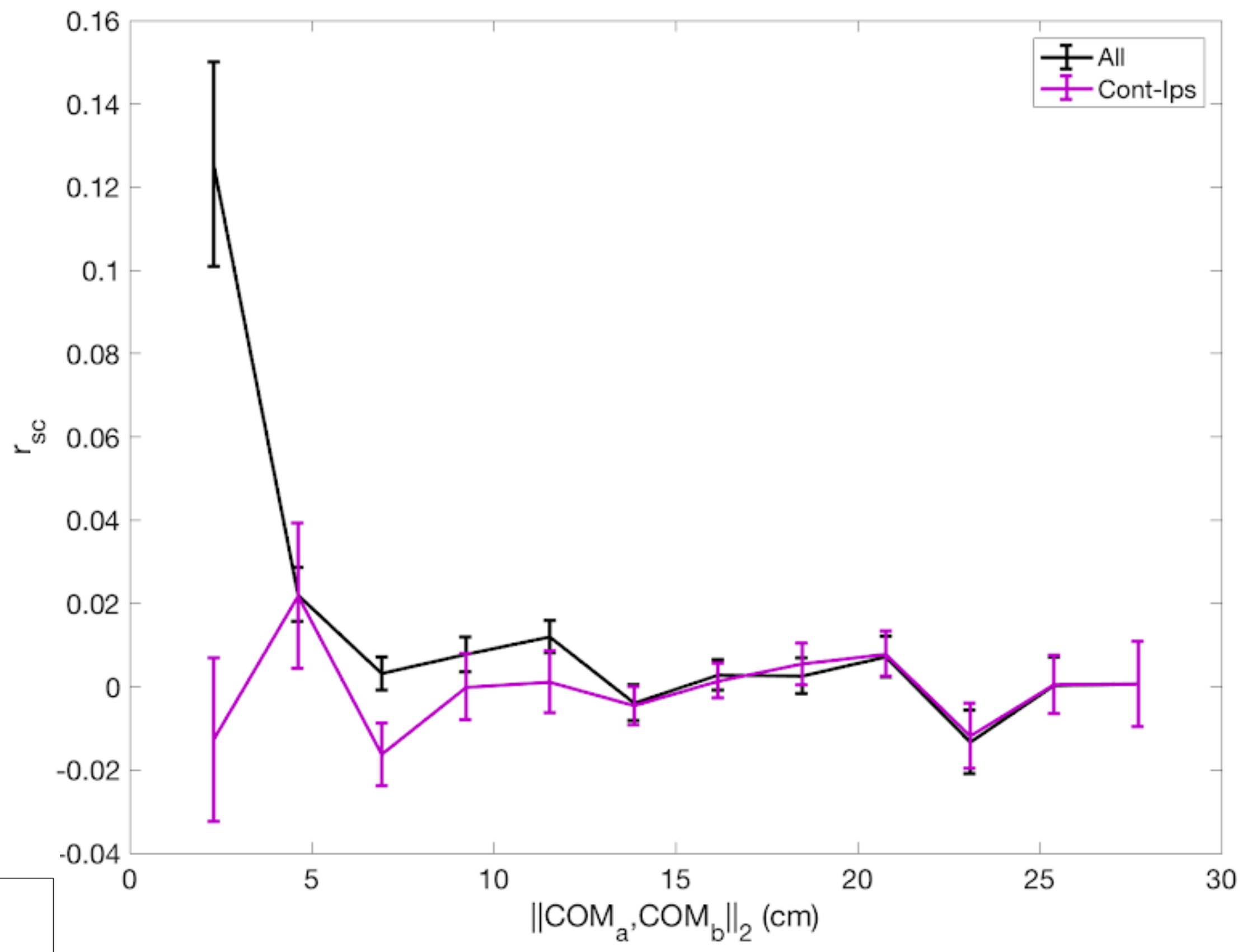
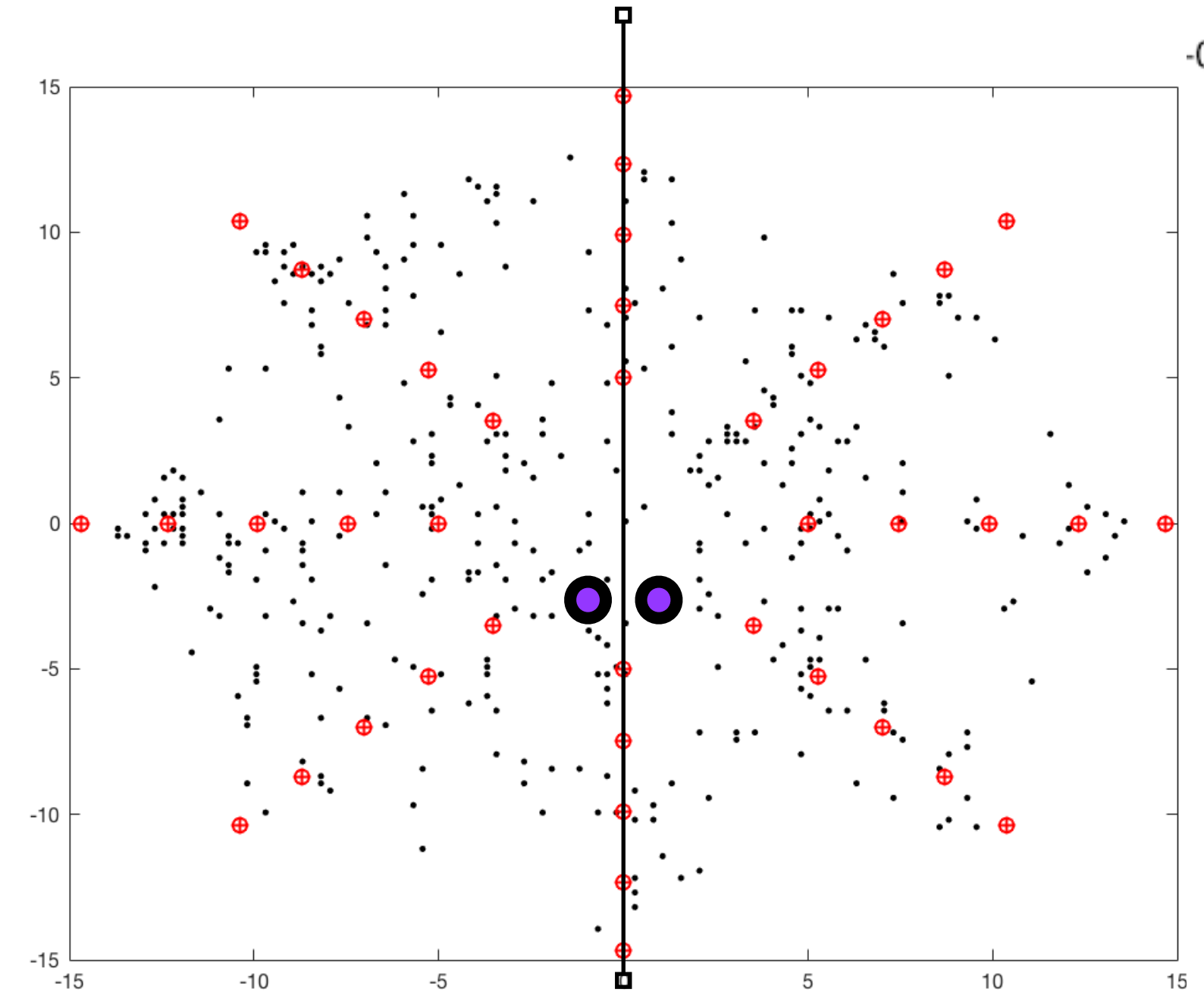
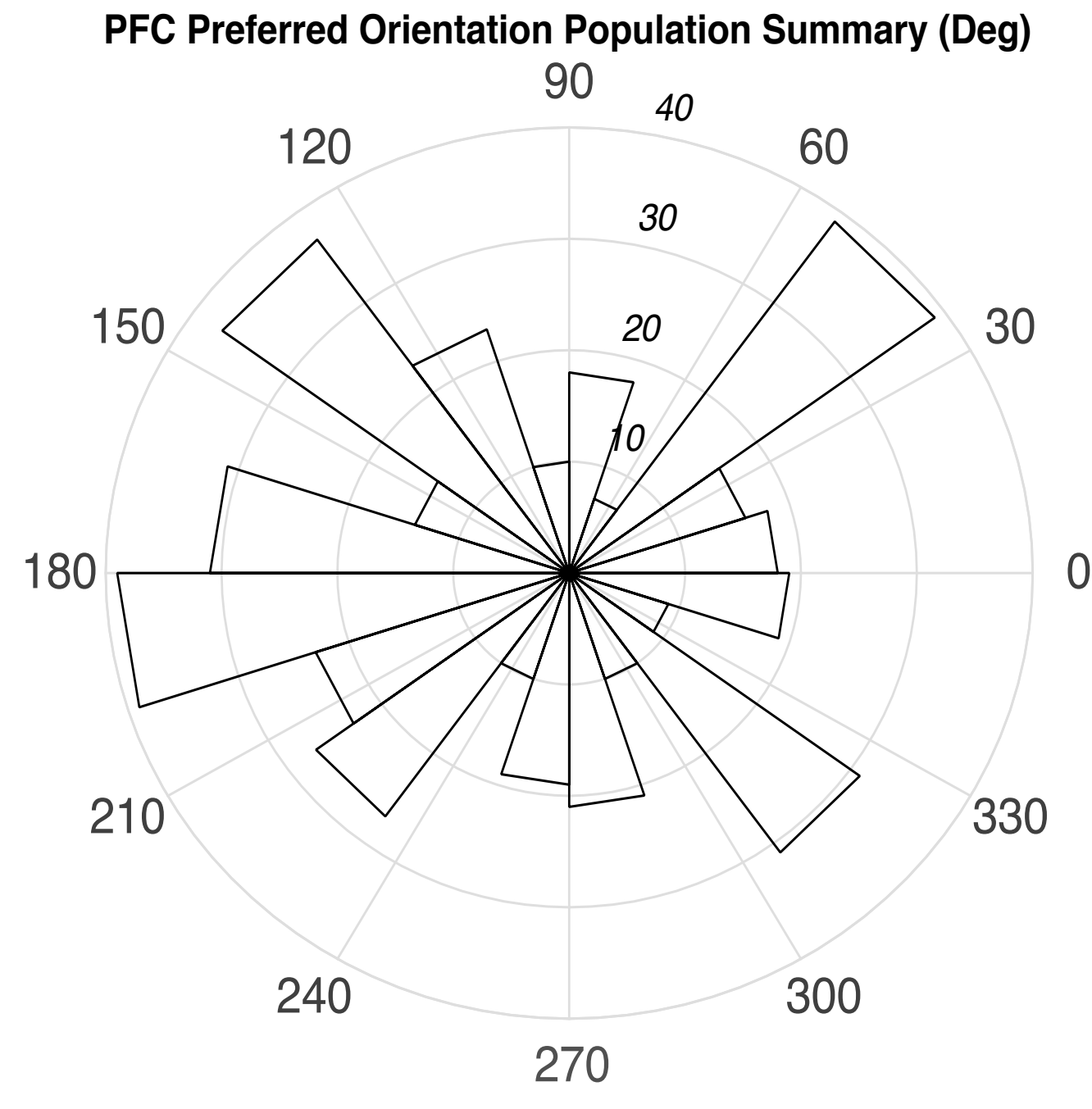
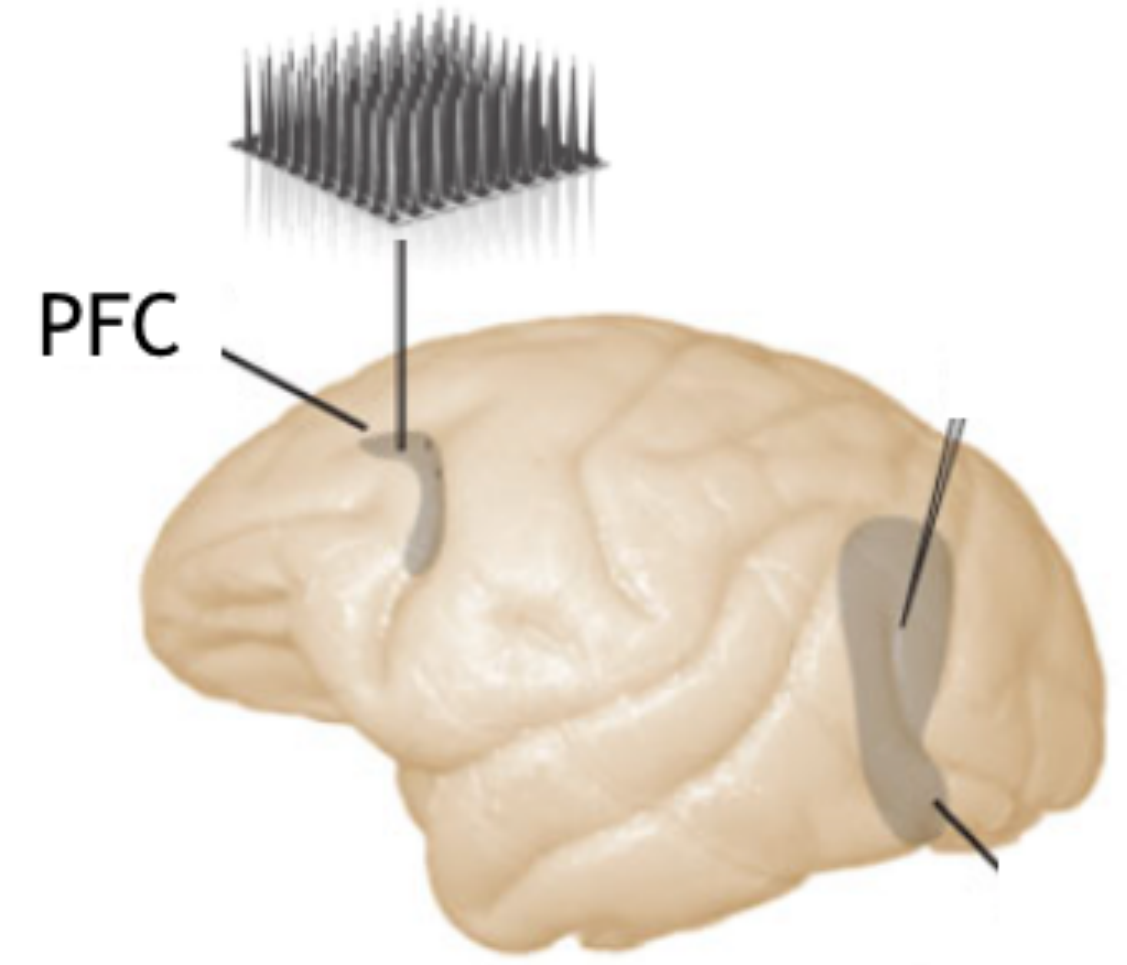
POPULATION DYNAMICS

PFC



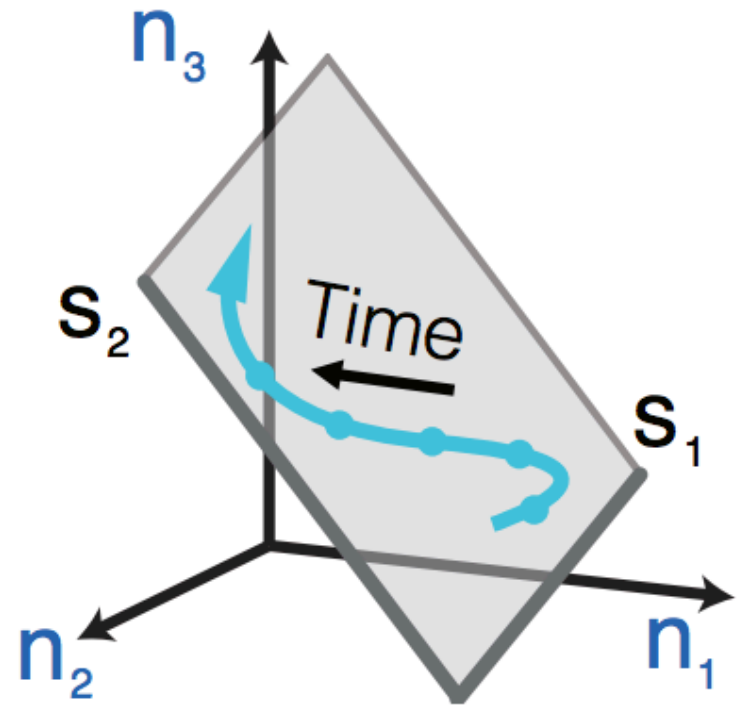
POPULATION DYNAMICS

PFC



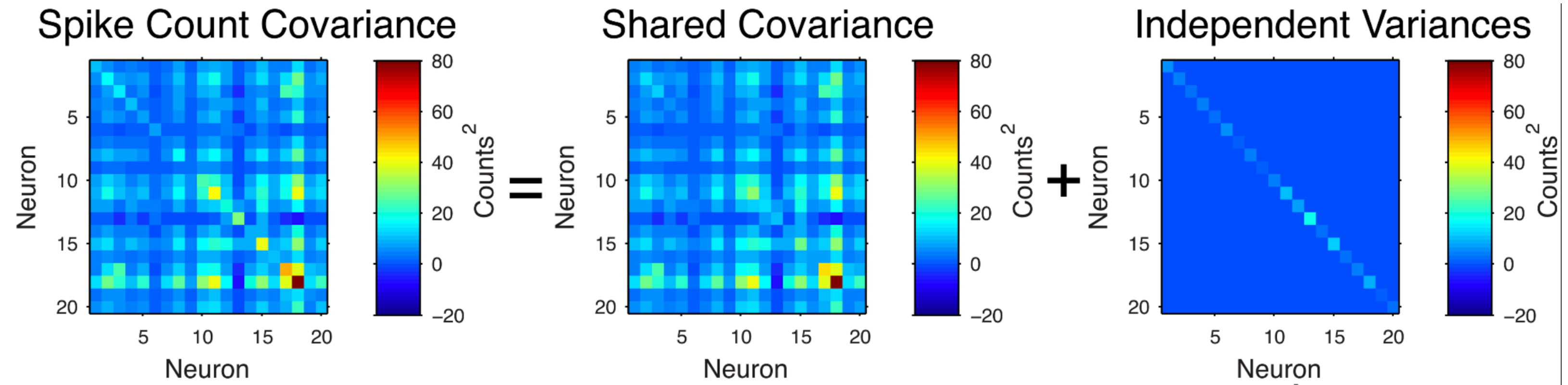
POPULATION DYNAMICS

Low dimensional structure?
Check with Factor Analysis.



$$\vec{y} - \vec{\mu} = \mathbf{C}\vec{x}$$

$$+ \vec{\epsilon} \sim N(0, \Psi)$$



V4

Low rank, ~1 latent dim

PFC

High rank, 10+ latent dims

“

Need to analyze the rank of the coordinated activity from a big neural population?”

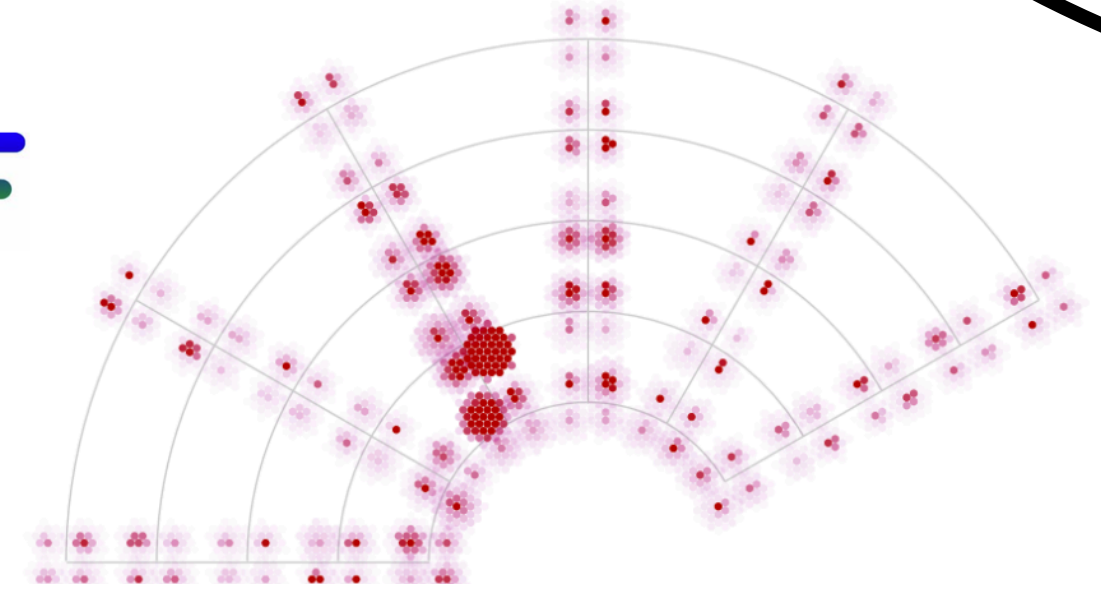
SFA SCALABLE FACTOR ANALYSIS IN SPARK



NATURE | NEWS

Brain-data gold mine could reveal how neurons compute

Allen Brain Observatory releases unprecedented survey of activity in the mouse visual cortex.



ALLEN BRAIN ATLAS DATA PORTAL

Data: Data Matrix $Y_{N \times D}$, int d

Result: Projection Matrix $C_{D \times d}$

$C = \text{normrnd}(D, d);$

$\Psi = \text{diag}(\text{normrand}(D, 1));$

$Y_m = \text{MeanSparkJob}(Y);$

$\text{Cov}(Y) = \text{CovSparkJob}(Y, Y_m);$

while not STOP_CONDITION do

$M = CC^T + \Psi;$

$C_{int} = C^T M^{-1};$

$X_m, \Sigma_{X_m}, Y_{proj} = \text{XYSparkJob}(Y, Y_m, C_{int});$

$C_{new} = Y_{proj} \Sigma_{X_m};$

$\Psi_{new} = \text{diag}(\text{Cov}(Y)) - \frac{1}{N} \text{diag}(C_{new} X_m Y_c^T);$

end

Algorithm 3: Final sFA algorithm, pseudocode

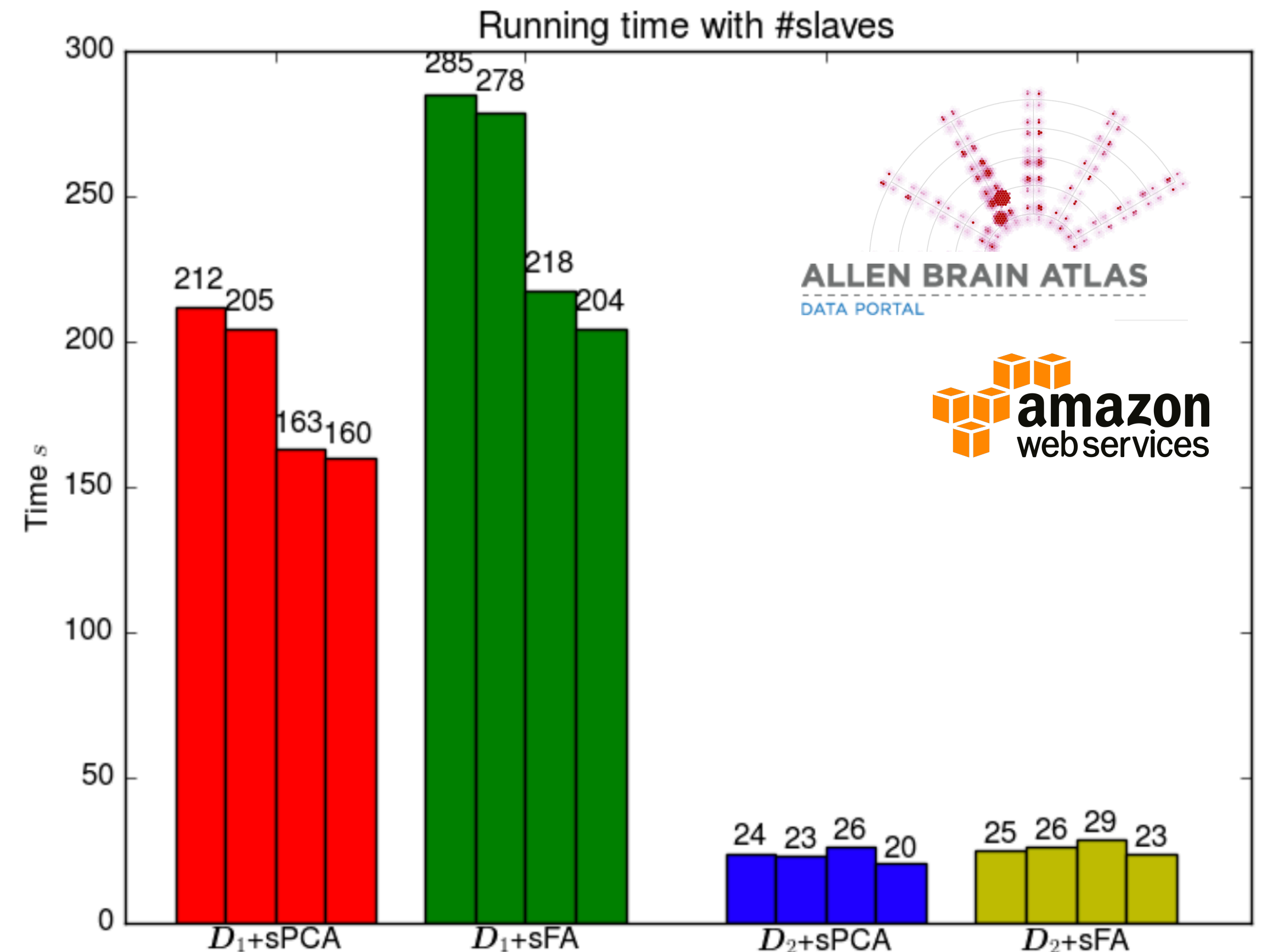
Scalable, Distributed Factor Analysis in Spark with Allen Brain Observatory Data

Danielle Rager
Carnegie Mellon University
5000 Forbes Ave
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Daoyuan Jia
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5000 Forbes Ave
Pittsburgh, Pennsylvania
tianchel@andrew.cmu.edu

- On largest matrix computations, use Apache Mahout for efficient, row-outer-product formulation
- Leverage matrix sparsity
- Performs nearly as well as sPCA



HOW DOES NETWORK CO-VARIABILITY:

1. Increase in dimensionality between V4 and PFC?

2. Drop to near 0 for PFC neurons with cue preferences across visual hemifields?

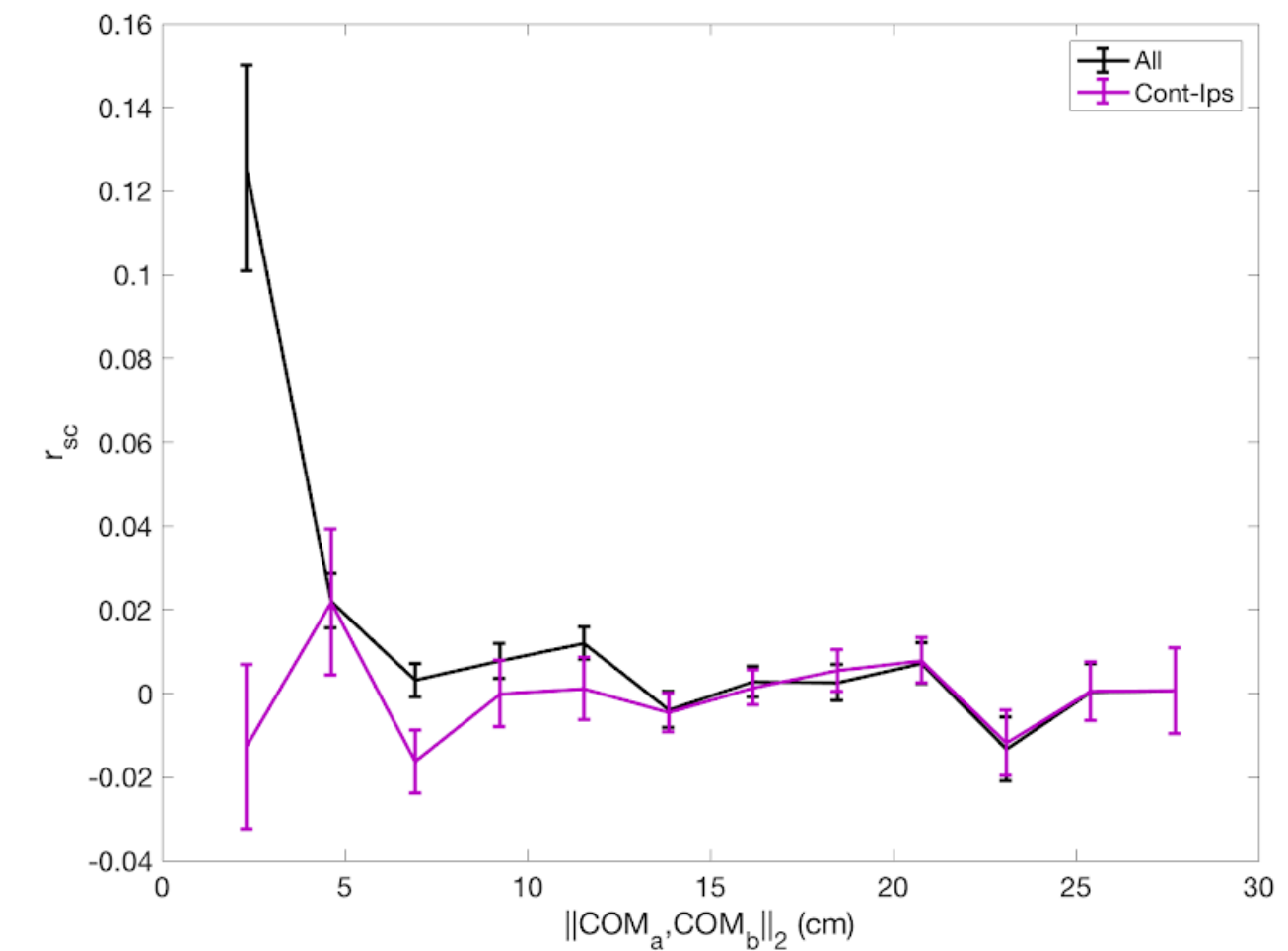
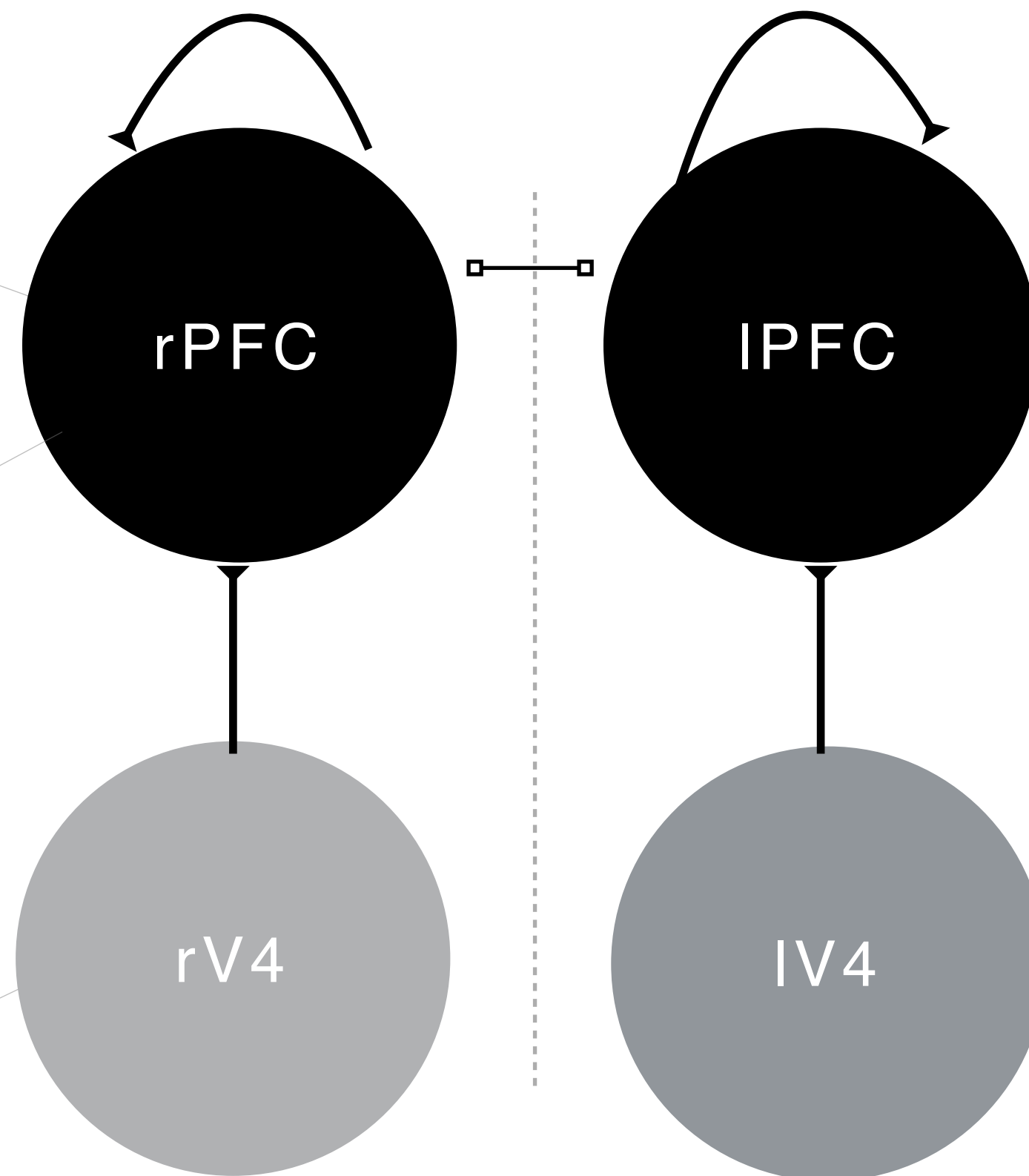
Strong self coupling within PFC hemispheres and weak or inhibitory negative coupling between hemispheres

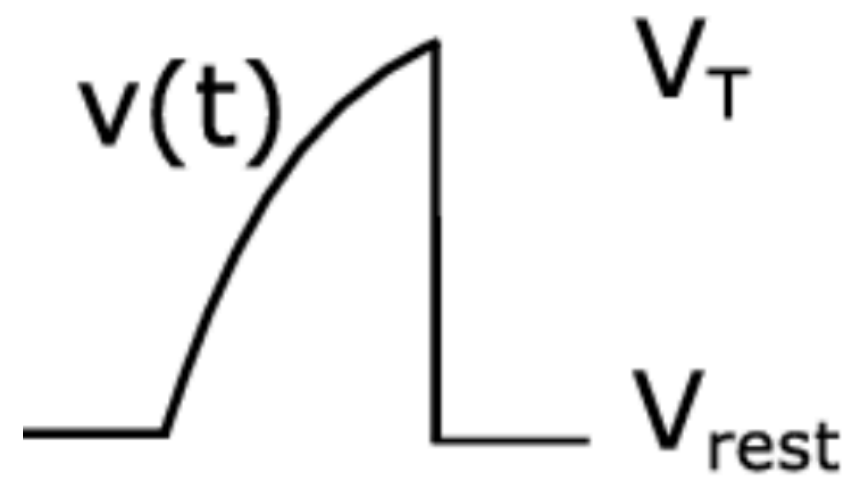
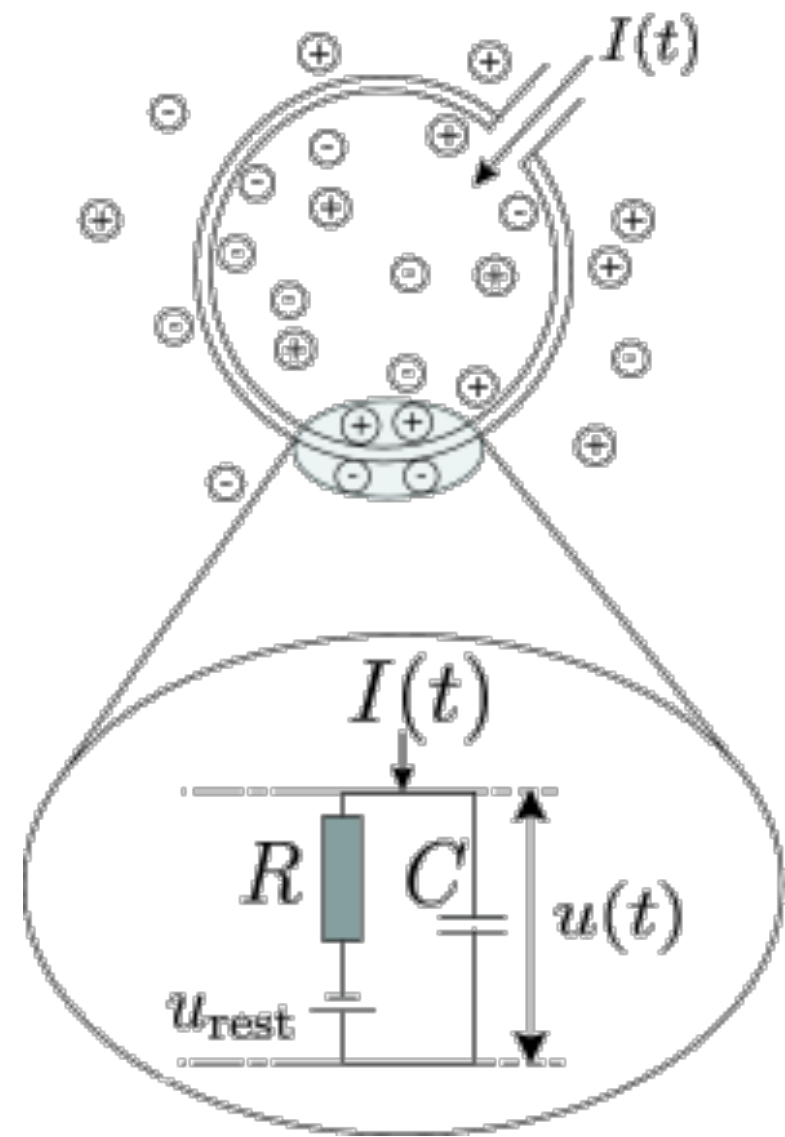
HIGH D STRUCTURE

How does this arise from PFC recurrent architecture?

LOW D STRUCTURE

Input layer: random spiking input with ~rank 1 covariance structure matches that of the data



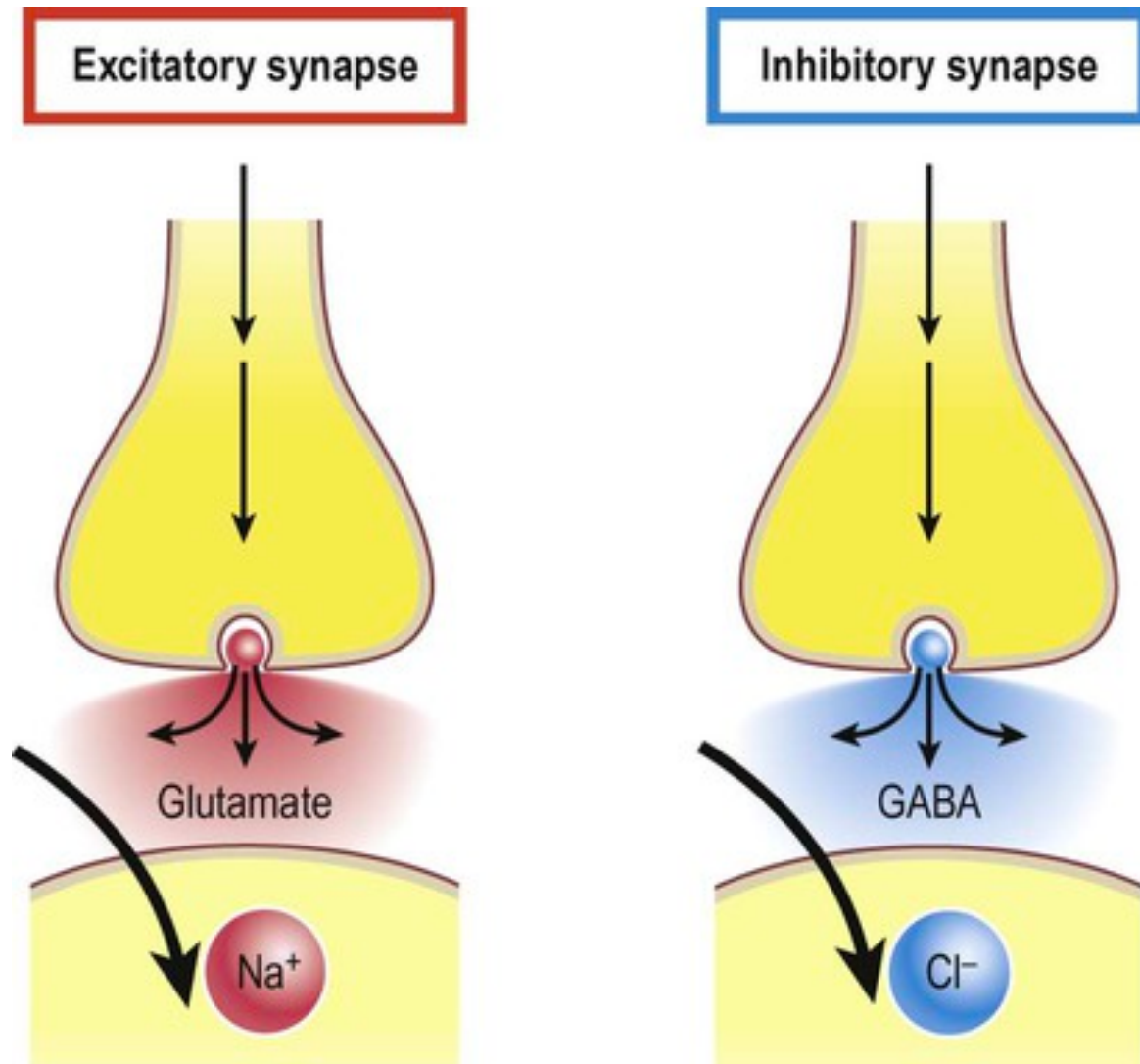


$$\dot{V} = \frac{1}{\tau} (\mu - V) + I_{syn}$$

CONNECT SPIKING UNITS WITH SIMPLE, GENERALIZABLE NETWORK WIRING RULES

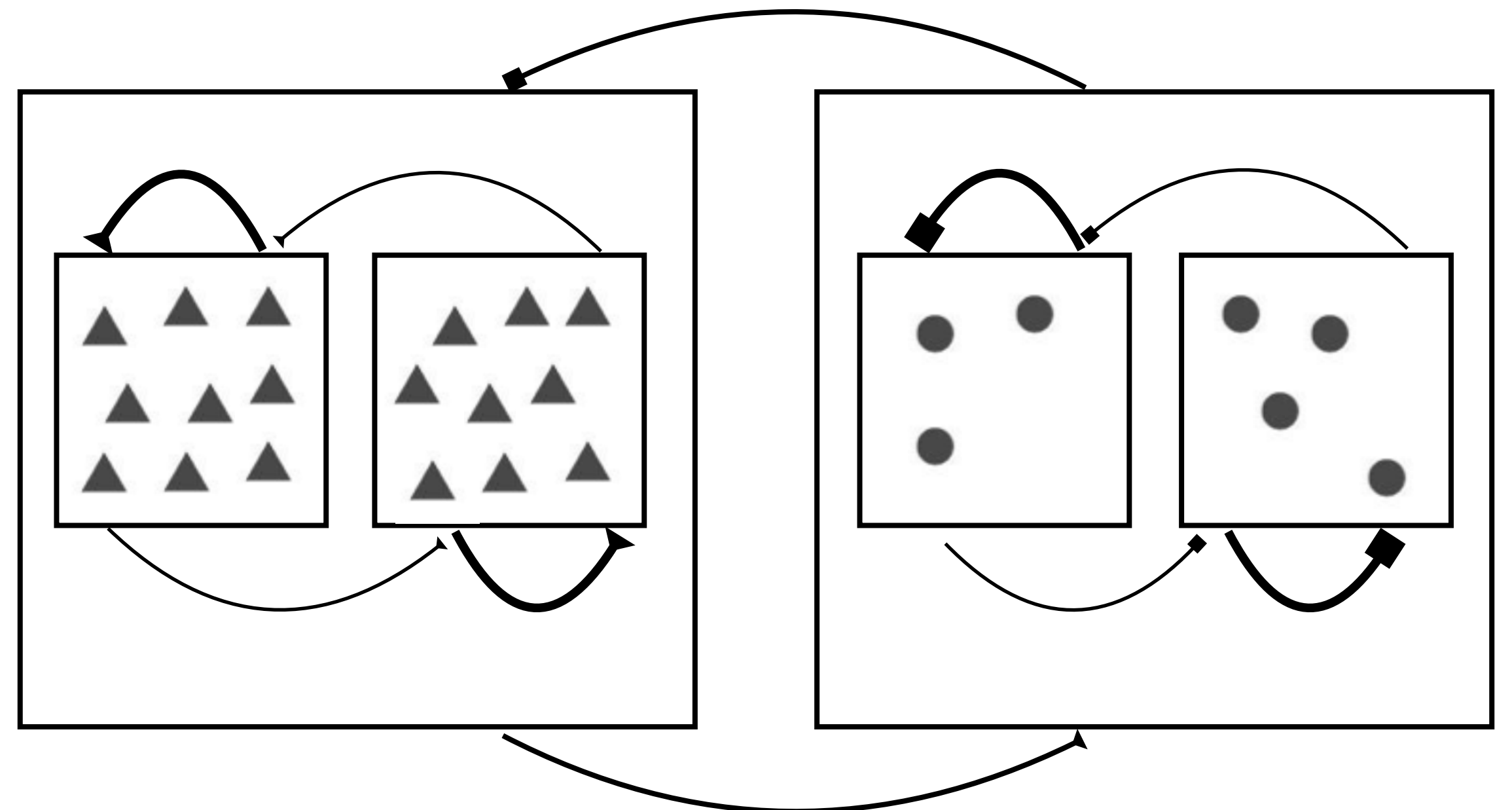
Connectivity based on properties like cell type, tuning, or membership to an assembly

DEVELOP MEAN FIELD INTUITIONS ABOUT POPULATION DYNAMICS



$$I_{i,syn}^x(t) = \sum_{jy} J_{ij}^{xy} F^y * s_j^y(t)$$

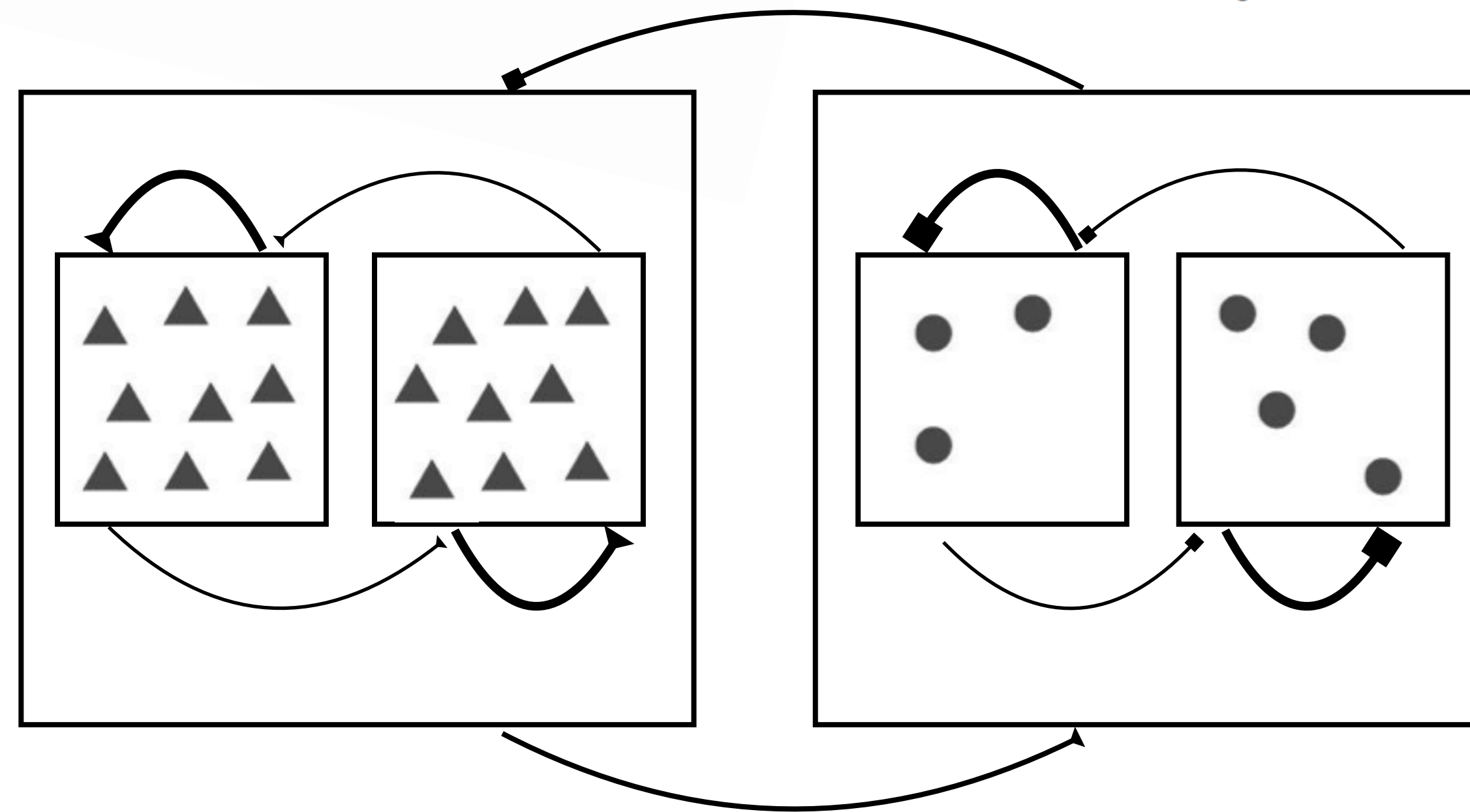
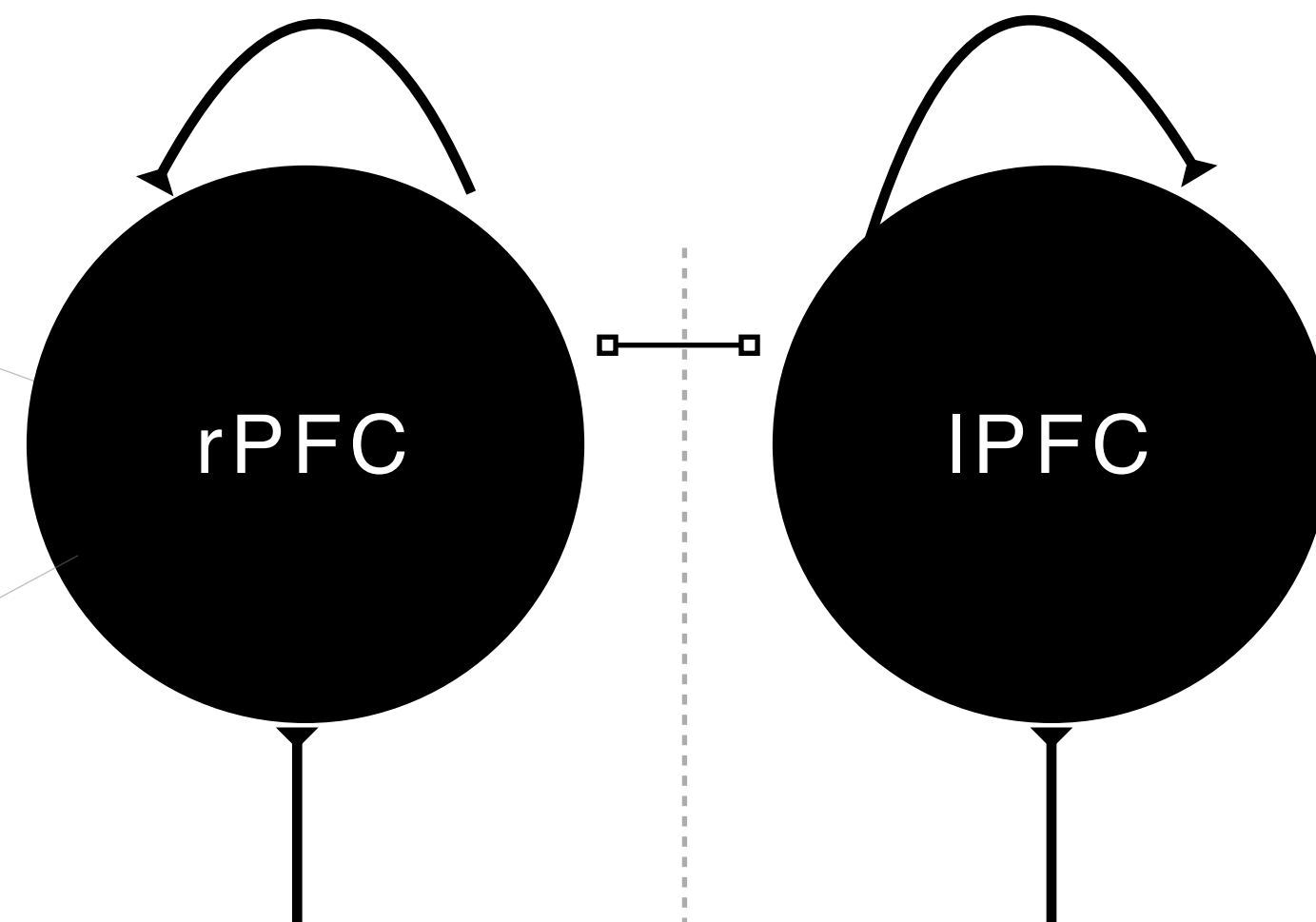
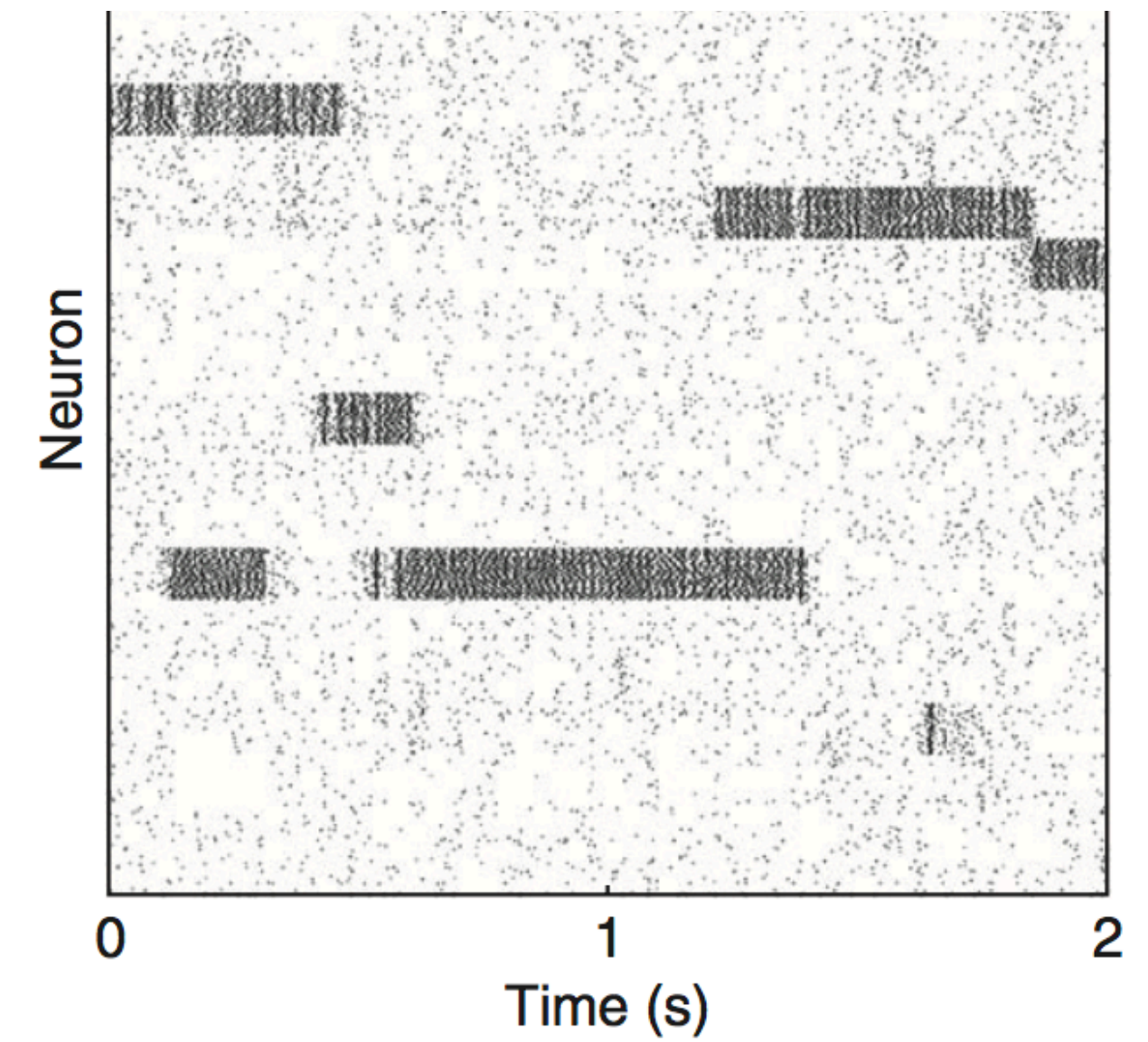
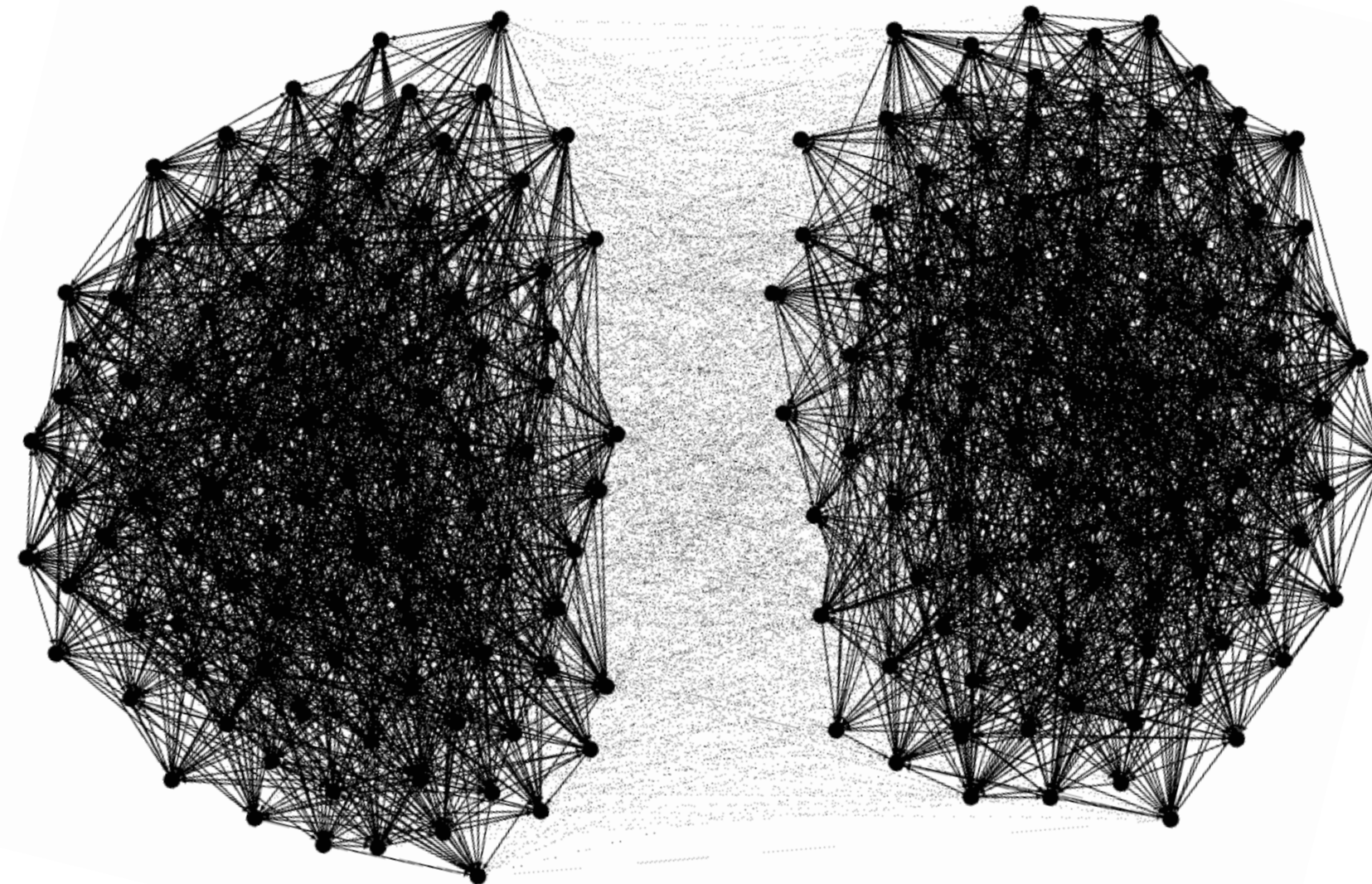
$$F^y(t) = \frac{1}{\tau_2 - \tau_1} \left(e^{-t/\tau_2} - e^{-t/\tau_1} \right)$$



GLOBAL BALANCE, LOCAL ASSEMBLY STRUCTURE

Slow dynamics and high variability in balanced cortical networks with clustered connections

Ashok Litwin-Kumar^{1,2} & Brent Doiron^{2,3}



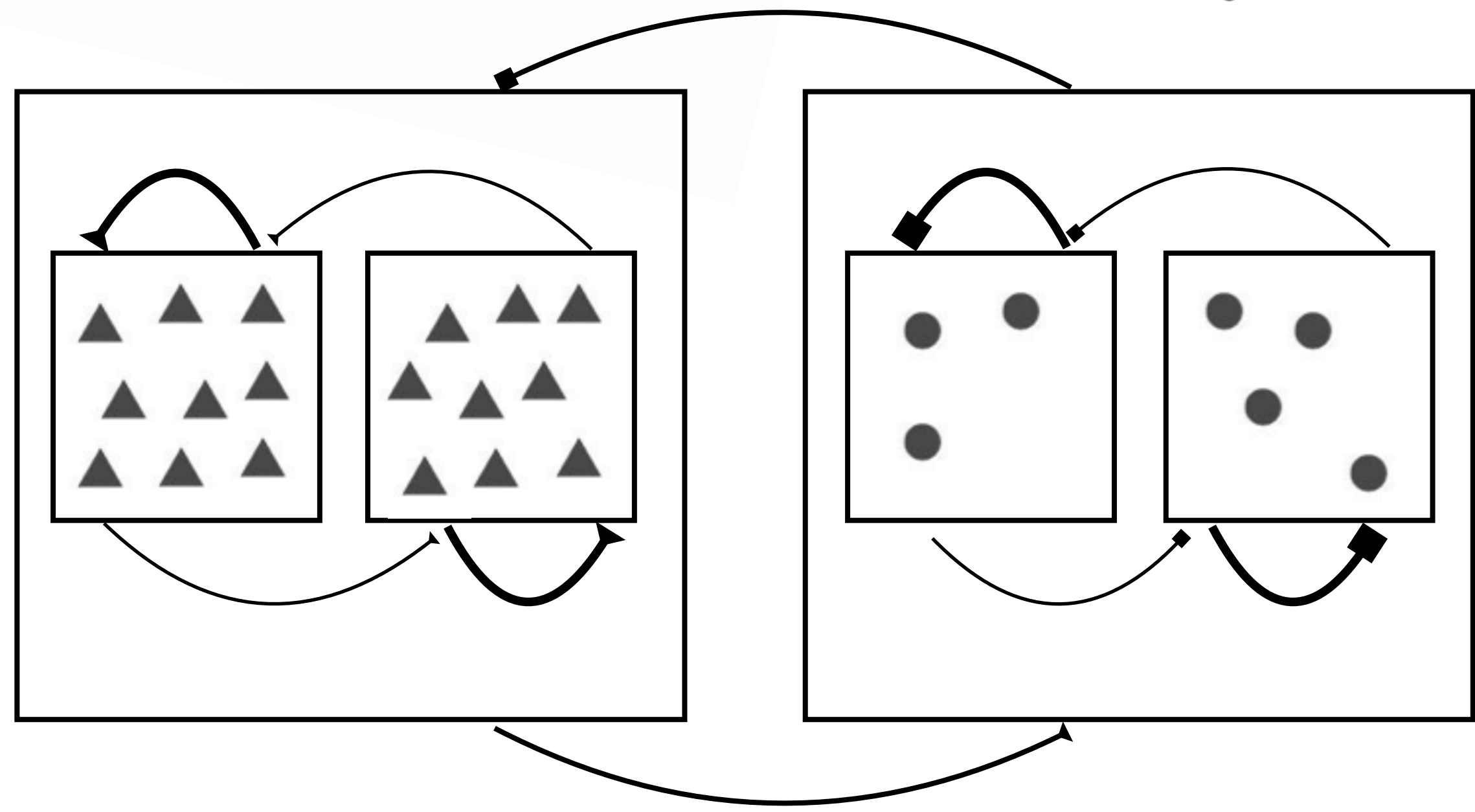
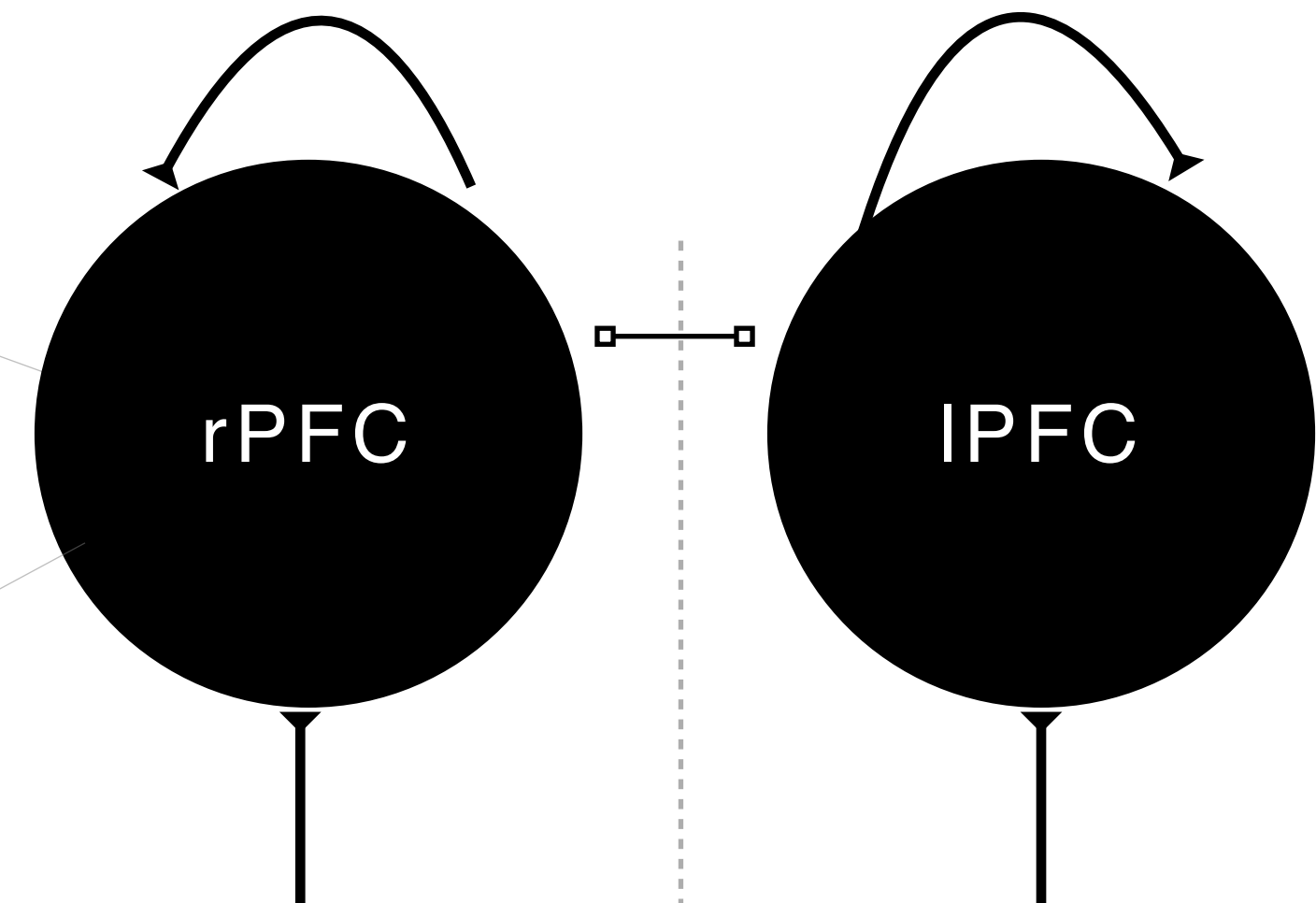
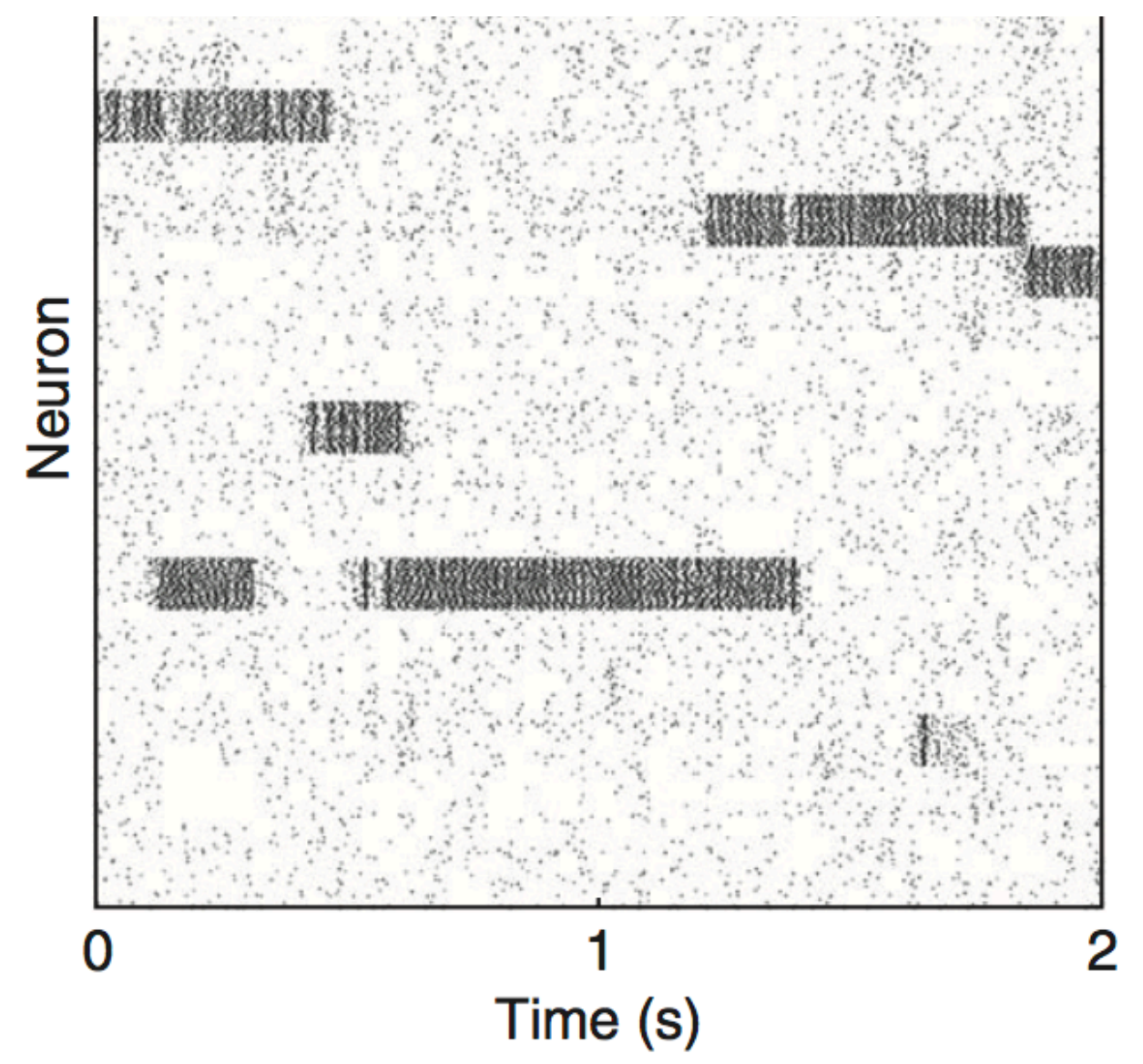
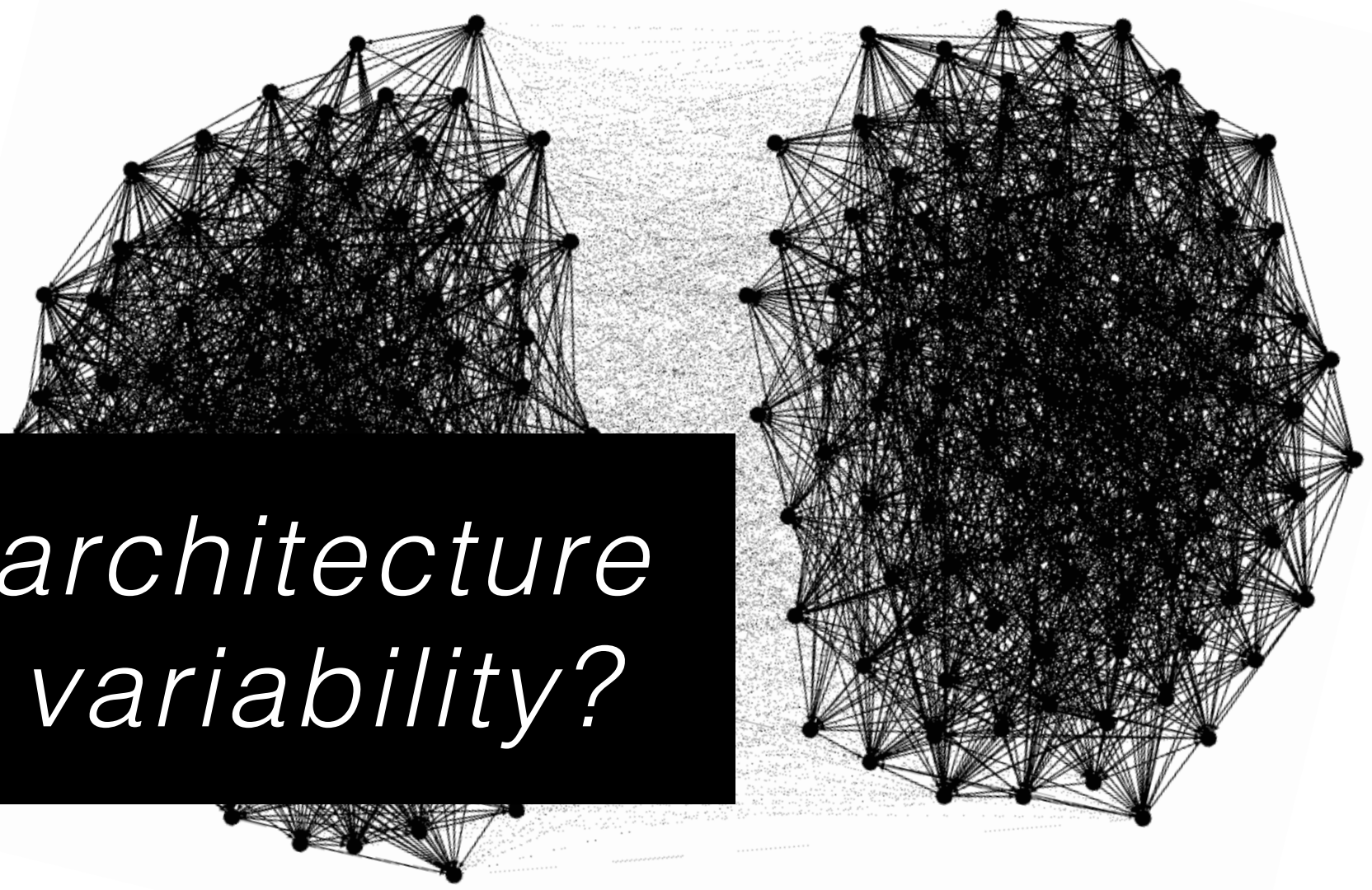
DEVELOP MEAN FIELD INTUITIONS ABOUT POPULATION DYNAMICS:

GLOBAL BALANCE, LOCAL ASSEMBLY STRUCTURE

Slow dynamics and high variability in balanced cortical networks with clustered connections

Ashok Litwin-Kumar^{1,2} & Brent Doiron^{2,3}

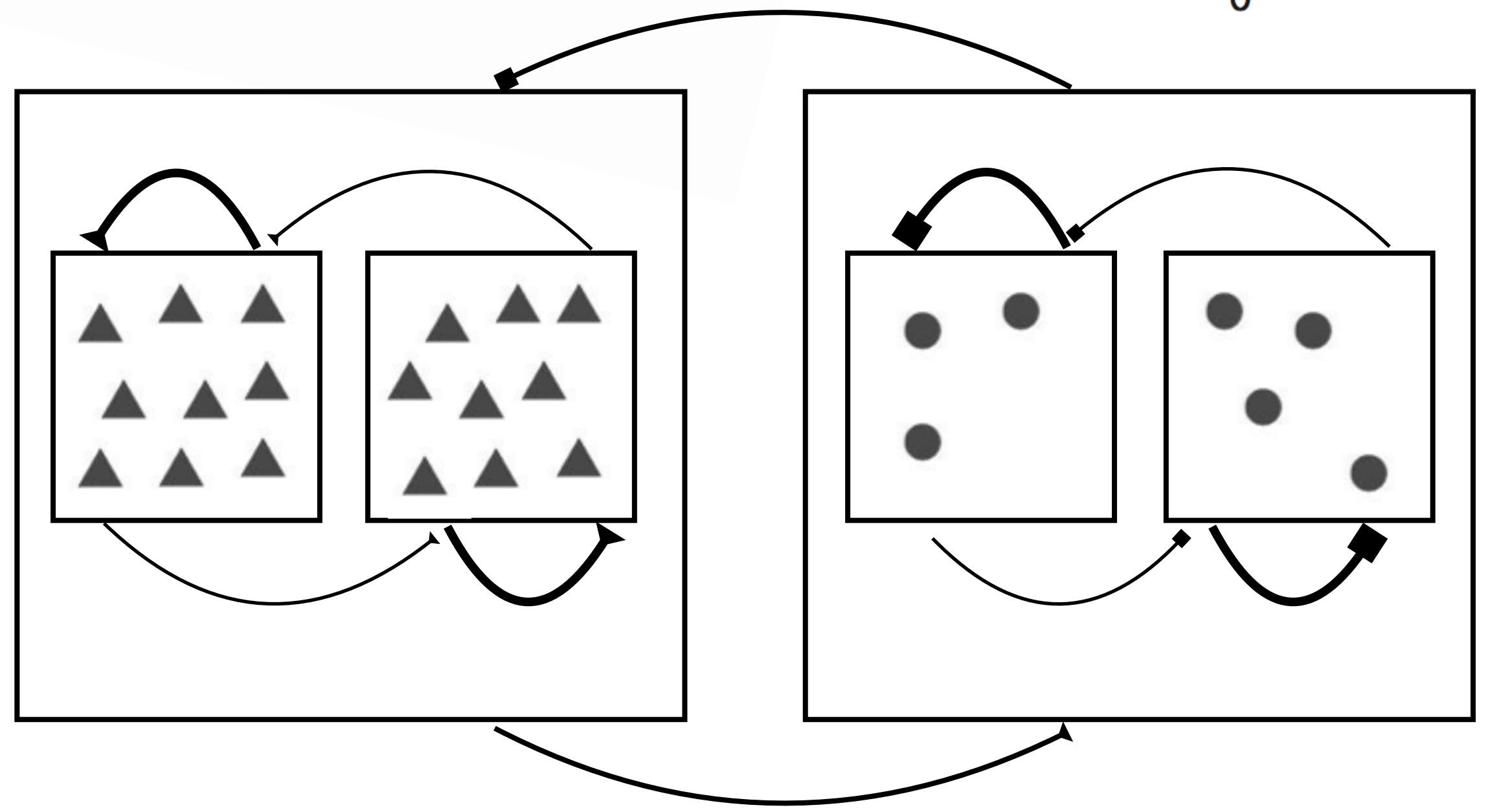
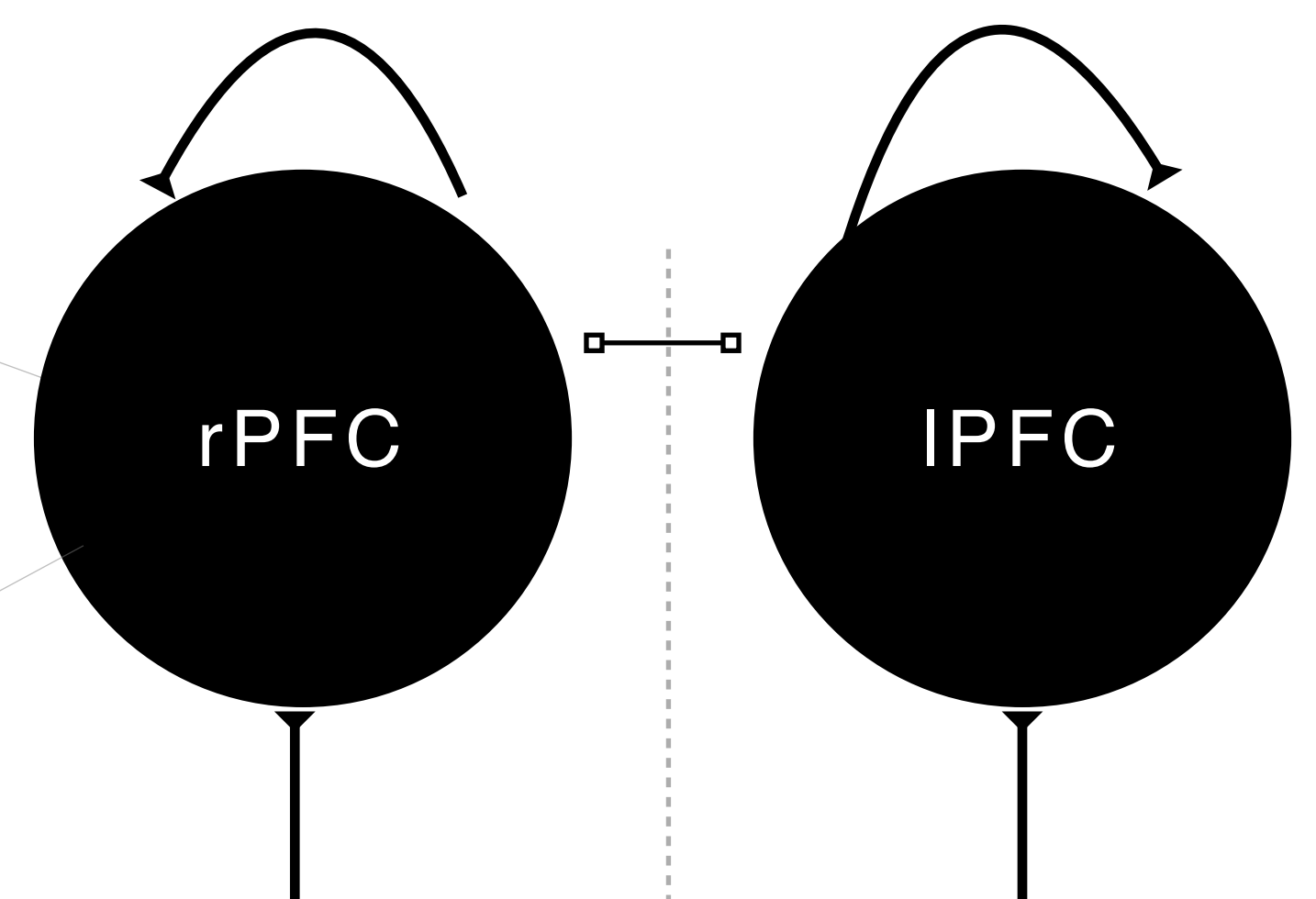
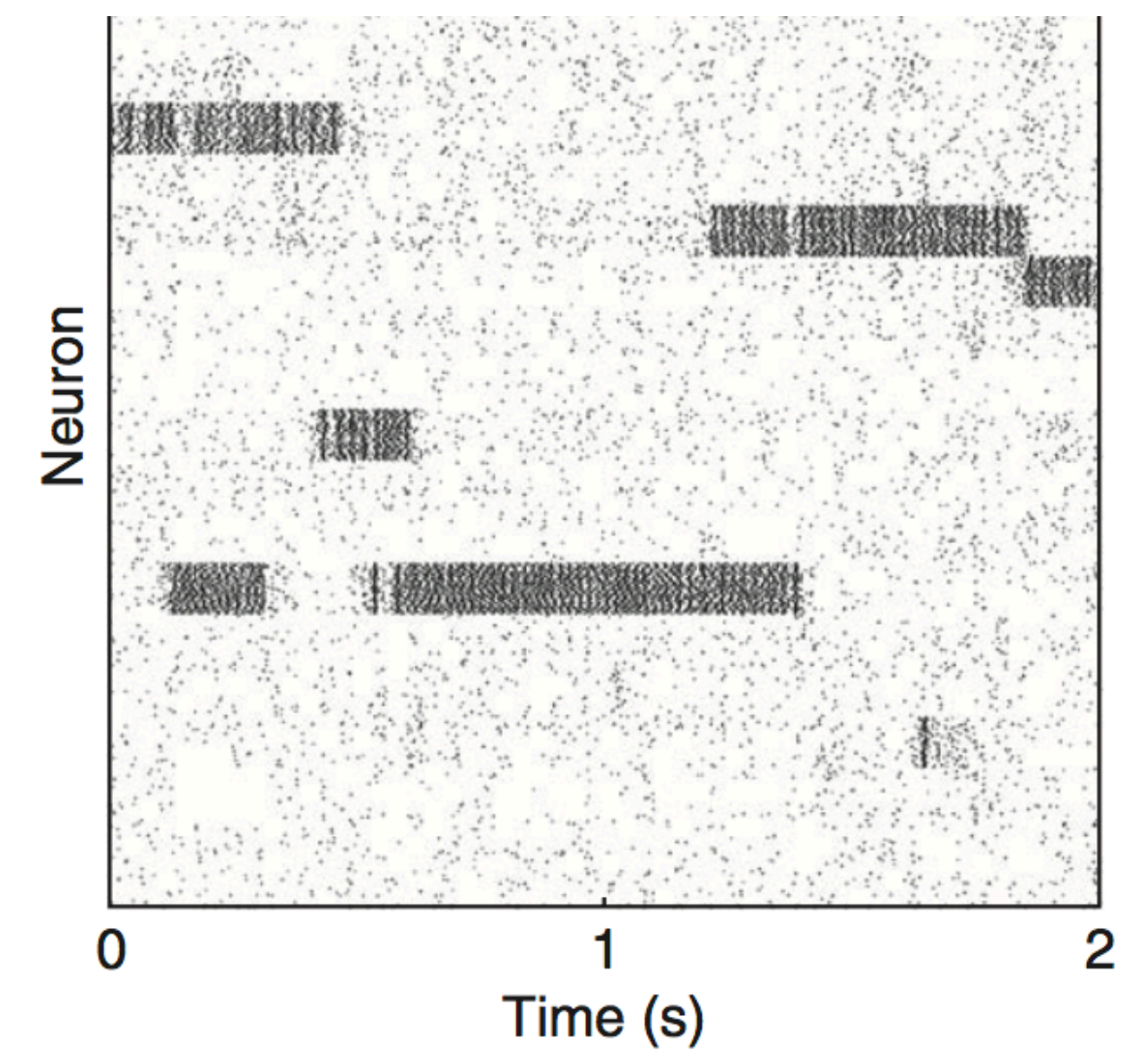
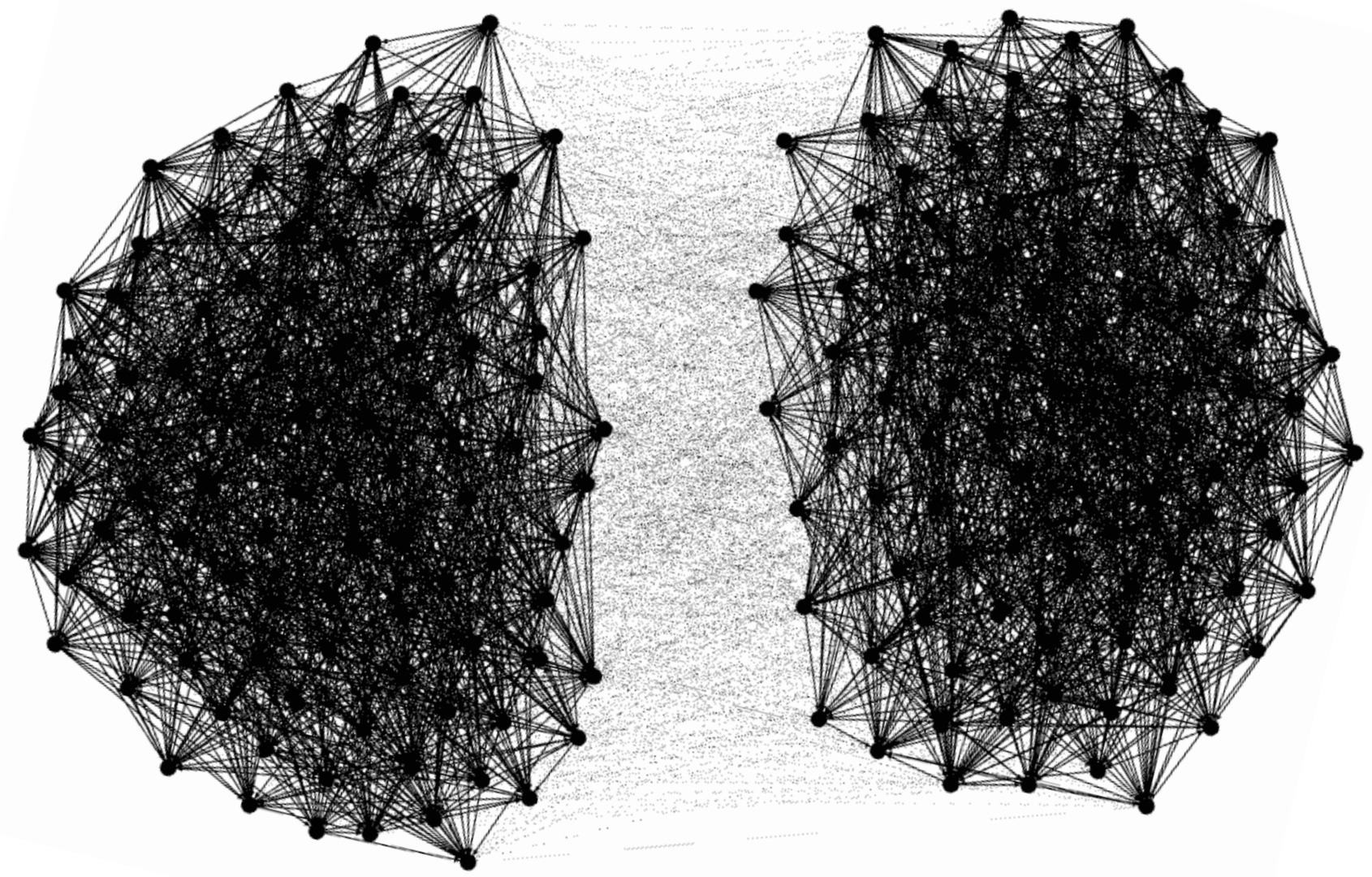
How does recurrent architecture in PFC filter network variability?

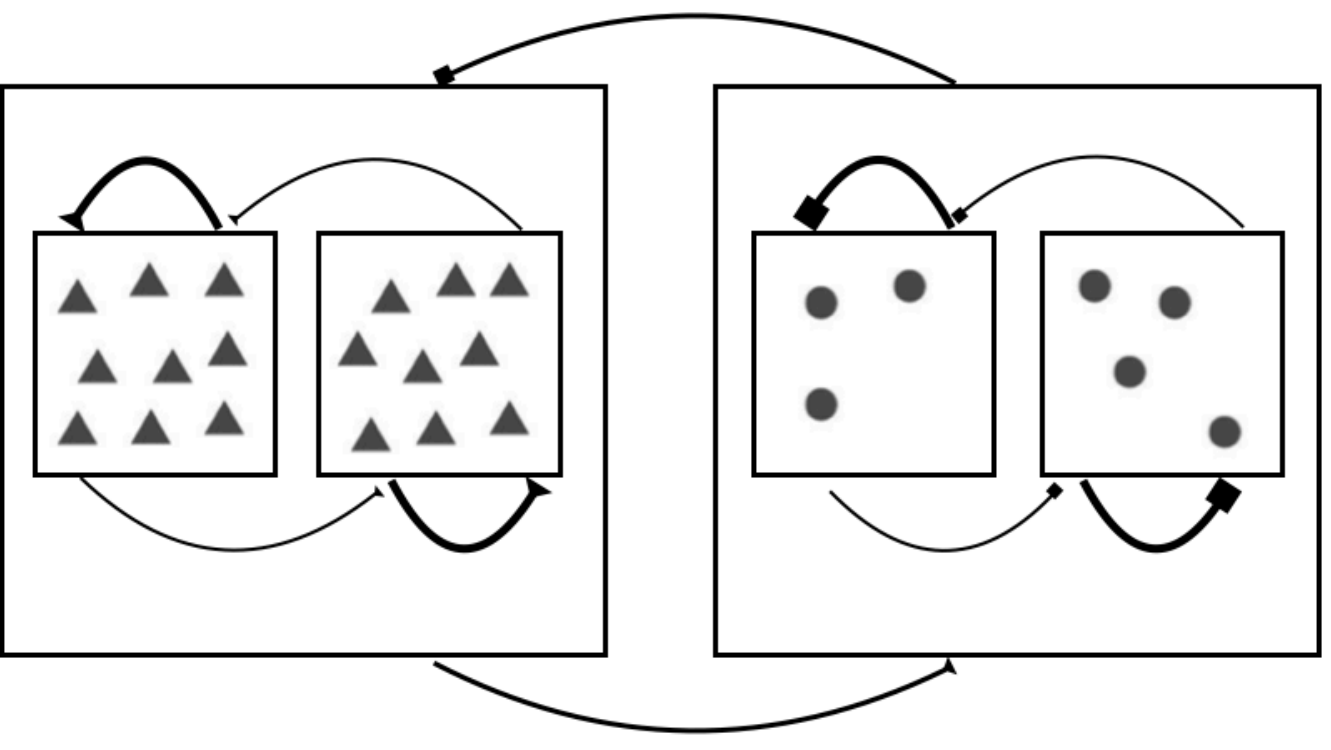


GLOBAL BALANCE, LOCAL ASSEMBLY STRUCTURE

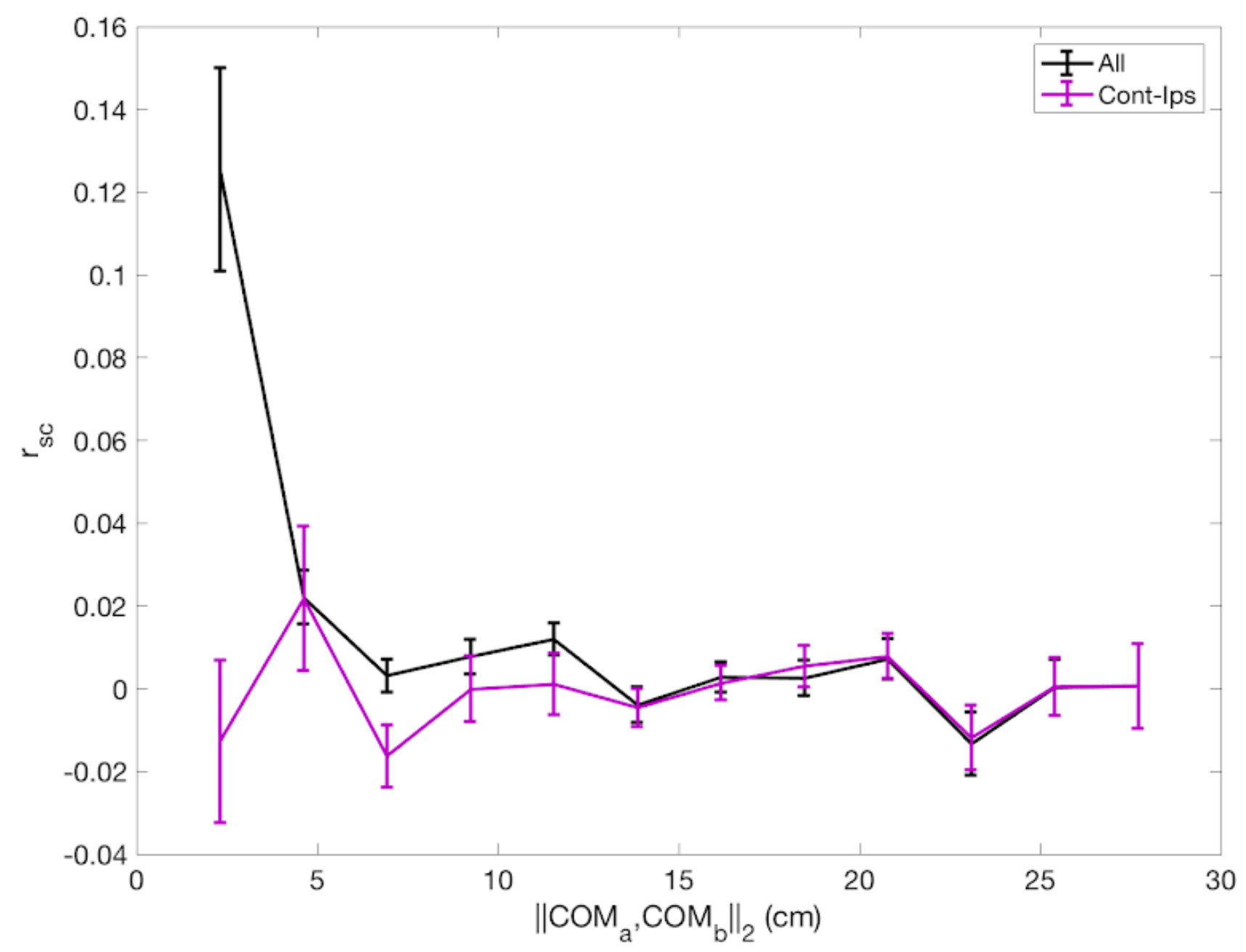
Slow dynamics and high variability in balanced cortical networks with clustered connections

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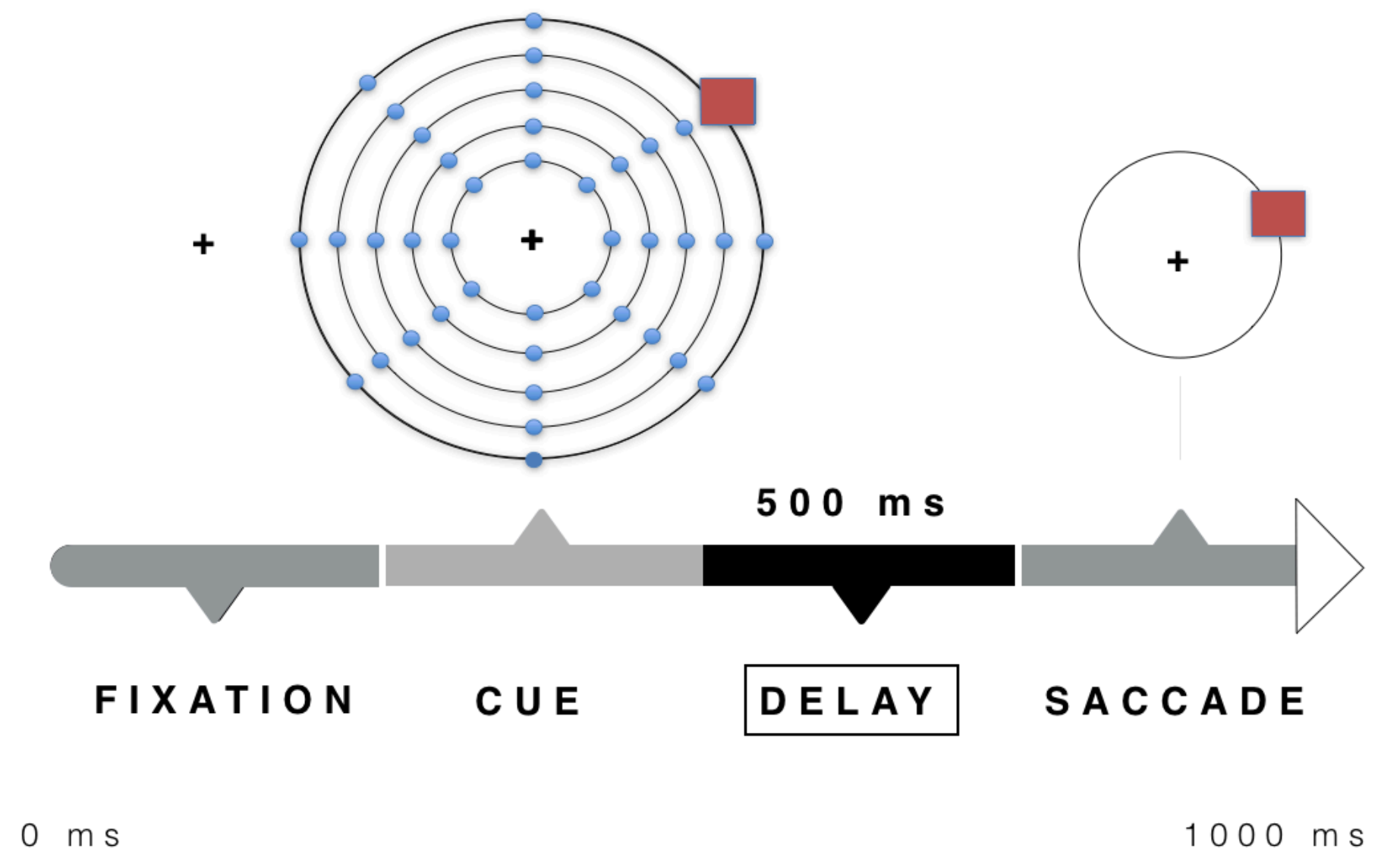
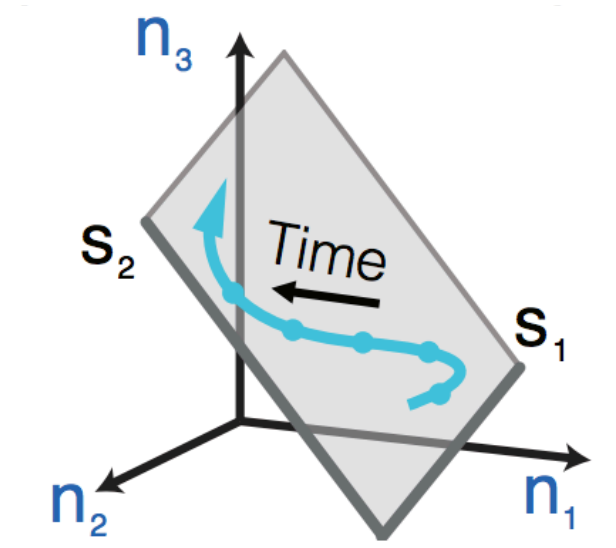




NETWORK MODEL



POPULATION DYNAMICS



BEHAVIOR / SENSORIMOTOR COMPUTATION

How does network architecture produce coordinated working memory computations?

ACKNOWLEDGEMENTS

 University of Pittsburgh

Department of
Mathematics



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UNIVERSITY OF PITTSBURGH
SWANSON school of engineering
bioengineering



SANJEEV KHANNA

University of Pittsburgh
Department of Neuroscience



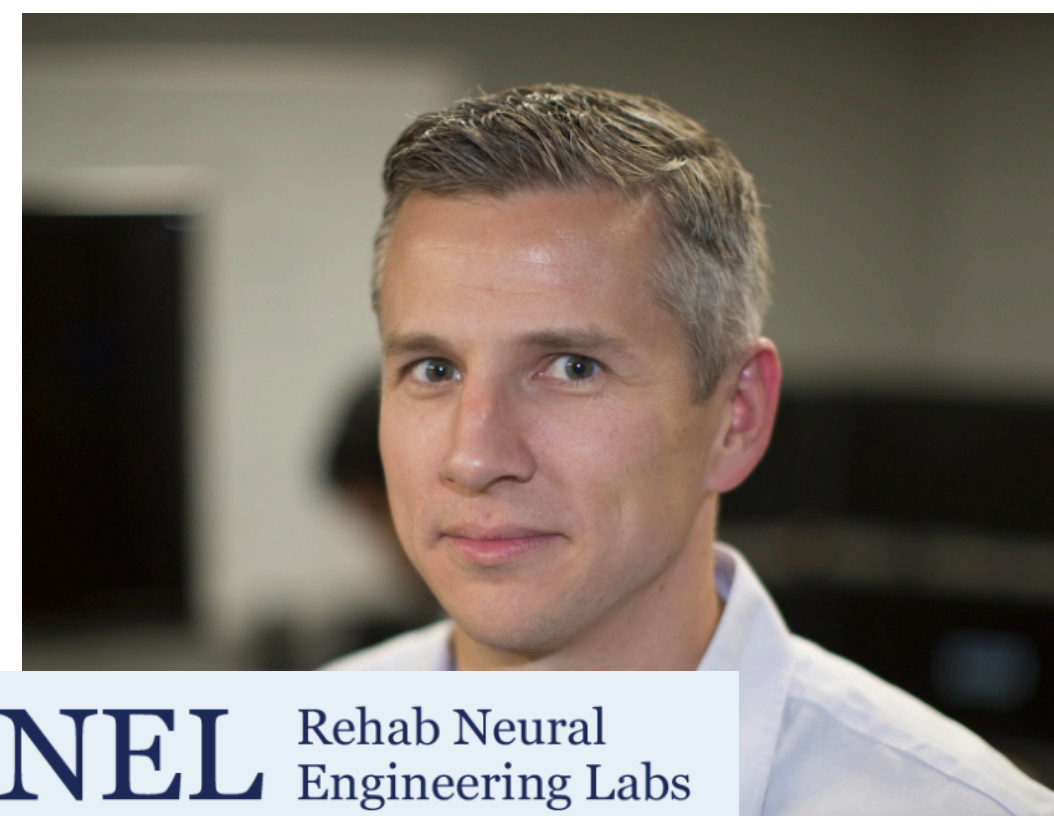
MATTHEW SMITH

VALERIE VENTURA



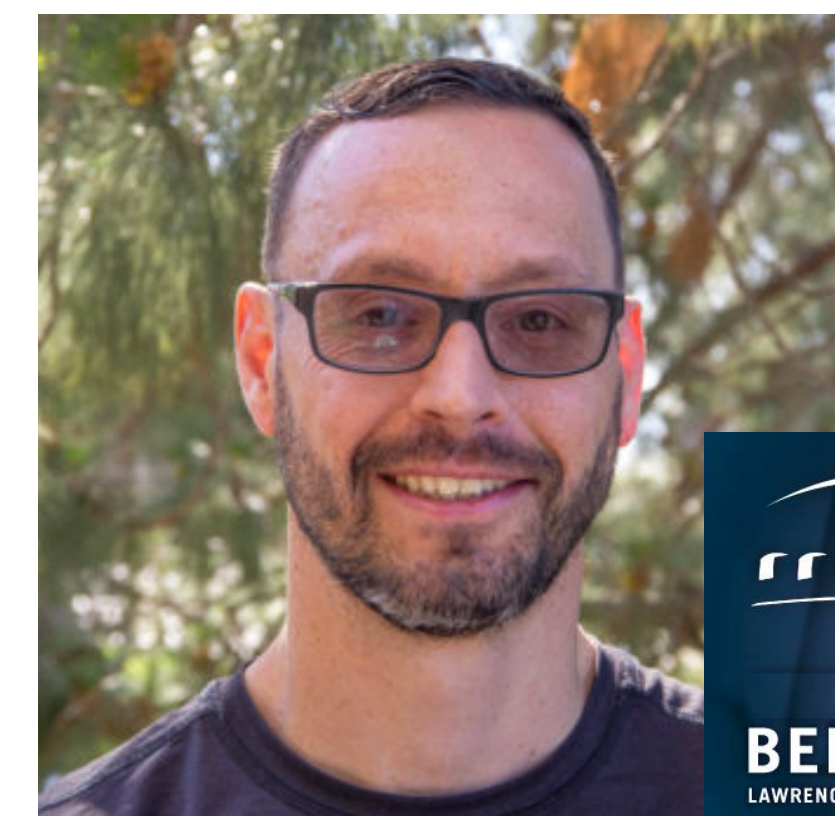
Carnegie Mellon University
Statistics & Data Science

ROB GAUNT

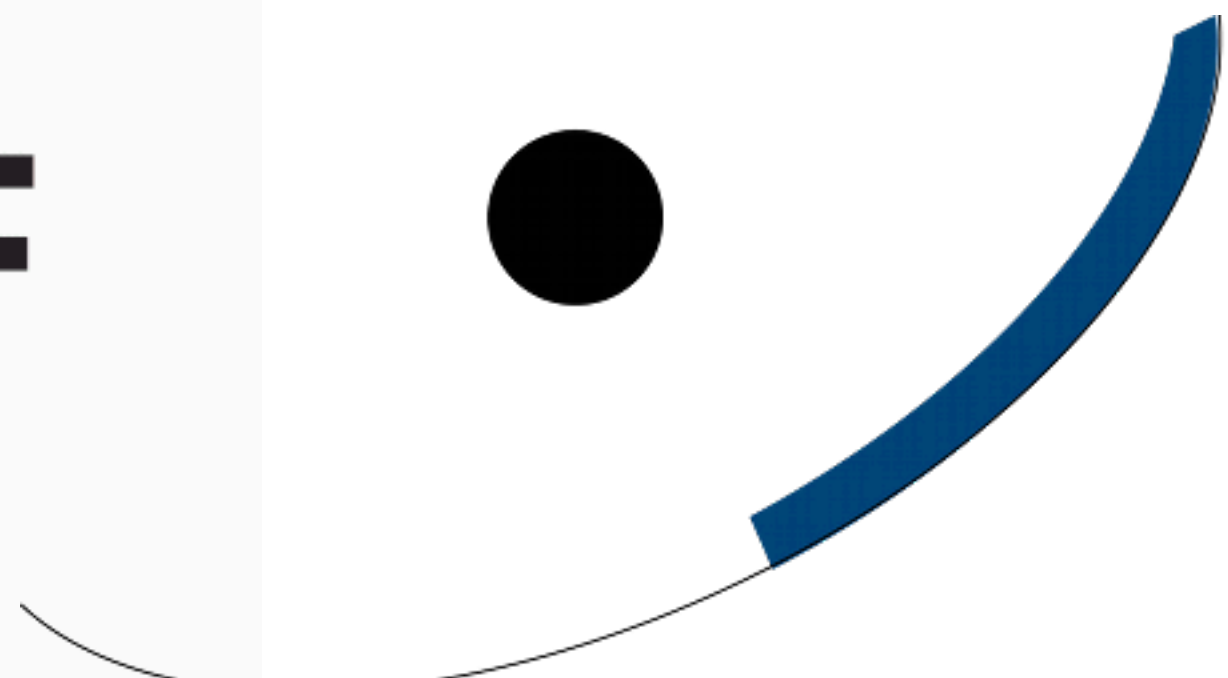


RNEL Rehab Neural
Engineering Labs

KRIS BOUCHARD




BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY



K R E L L
i n s t i t u t e