



Shared dynamics with distinct population geometries across brain areas during decision-making

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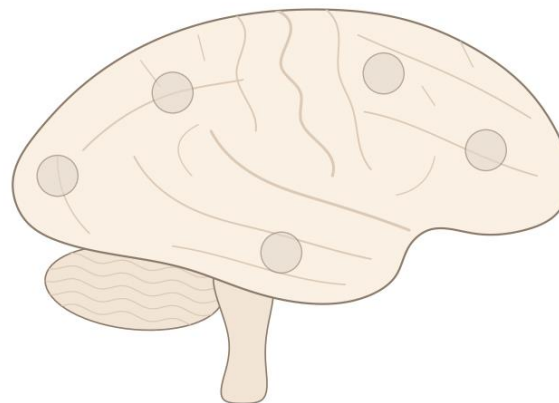
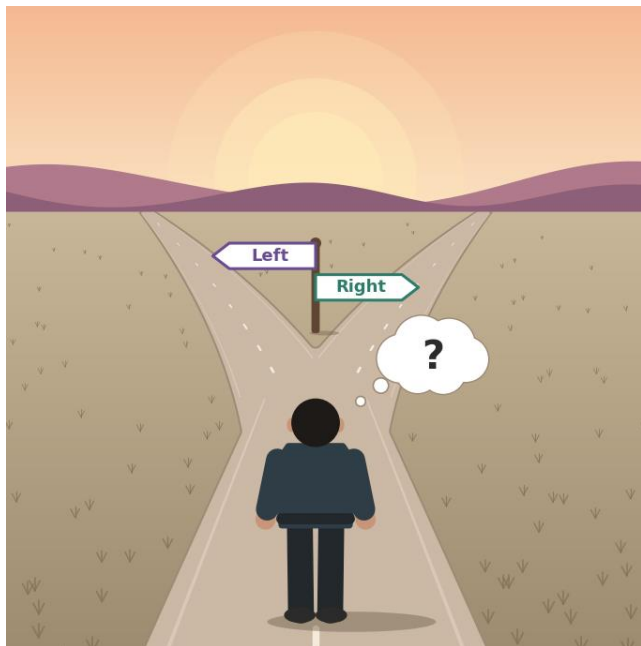
Sant'Anna School of Advanced Studies
The BioRobotics Institute, Pisa, Italy.

UniCam School of Advanced Studies, Center for
Neuroscience, University of Camerino, Camerino, Italy.

Context and scientific question

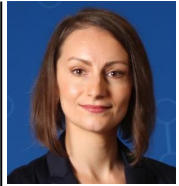
Does the variability of neural activity across brain regions reflect:

- distinct dynamics of the cognitive variable?
- area-specific responses to the same underlying dynamics?



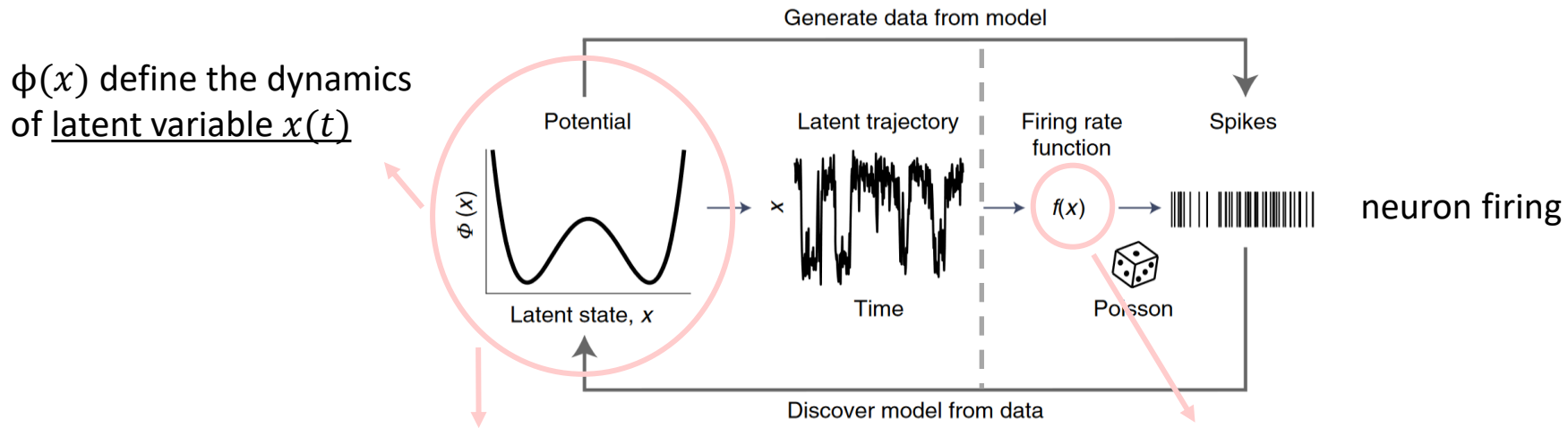
We used a data-driven latent-state model to infer simultaneously the dynamics and the neural response using only spike time series.

Computational framework - NeuralFlow

Tatiana
Engel

NeuralFlow models neural spiking activity using 1D continuous latent Langevin dynamics.

Potential function $\phi(x)$ $\dot{x} = -D \frac{d\Phi(x)}{dx} + \sqrt{2D}\xi(t)$ Gaussian noise $\xi(x)$ of magnitude D



Necessary the **initial condition** x_0

Inhomogeneous Poisson process with **tuning function** $f(x)$:

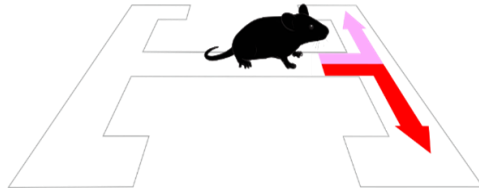
$$\lambda(t) = f_i(x(t))$$

Experiment and dataset



M. Jones

5 rats
2 sessions



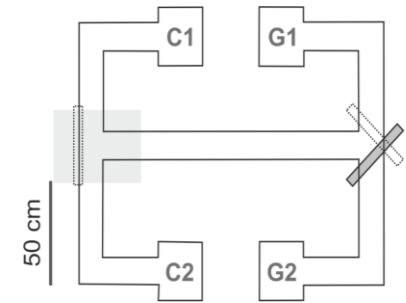
- Hippocampus (**HC**)
- Parietal Cortex (**PC**)
- Pre-Frontal Cortex (**PFC**)



simultaneously recorded

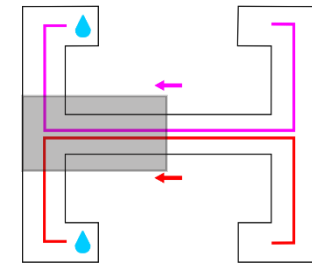
From G to C (*choice trials*)

From C to G (*guided trials*)



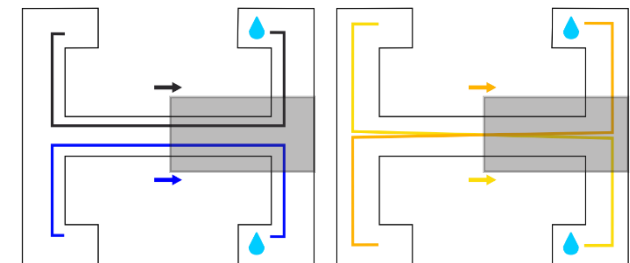
Data for
choice trials

Two correct choice trials



Data for
guided trials

Four possible guided trials

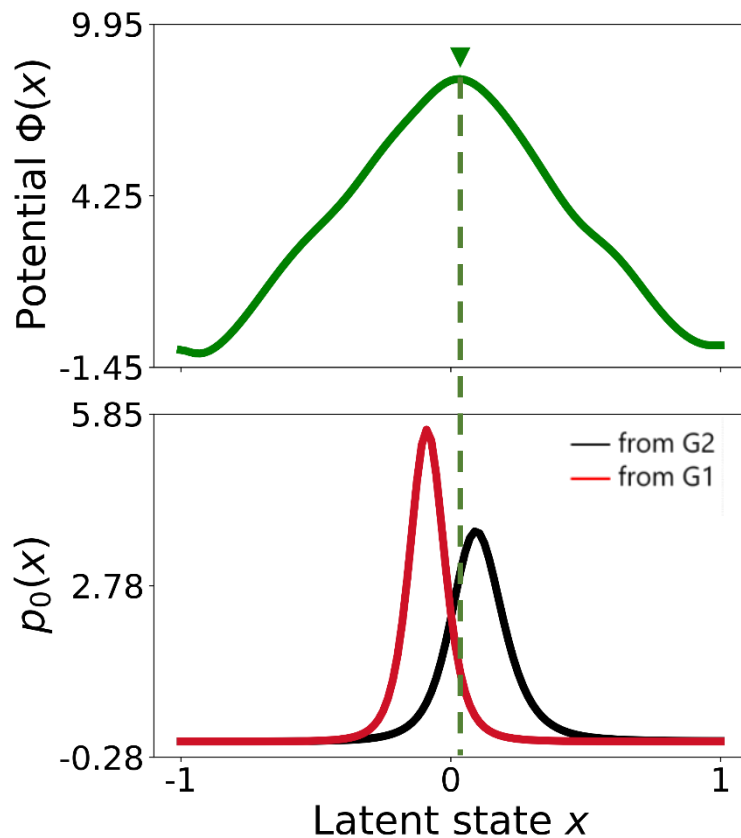


Single session results – overview

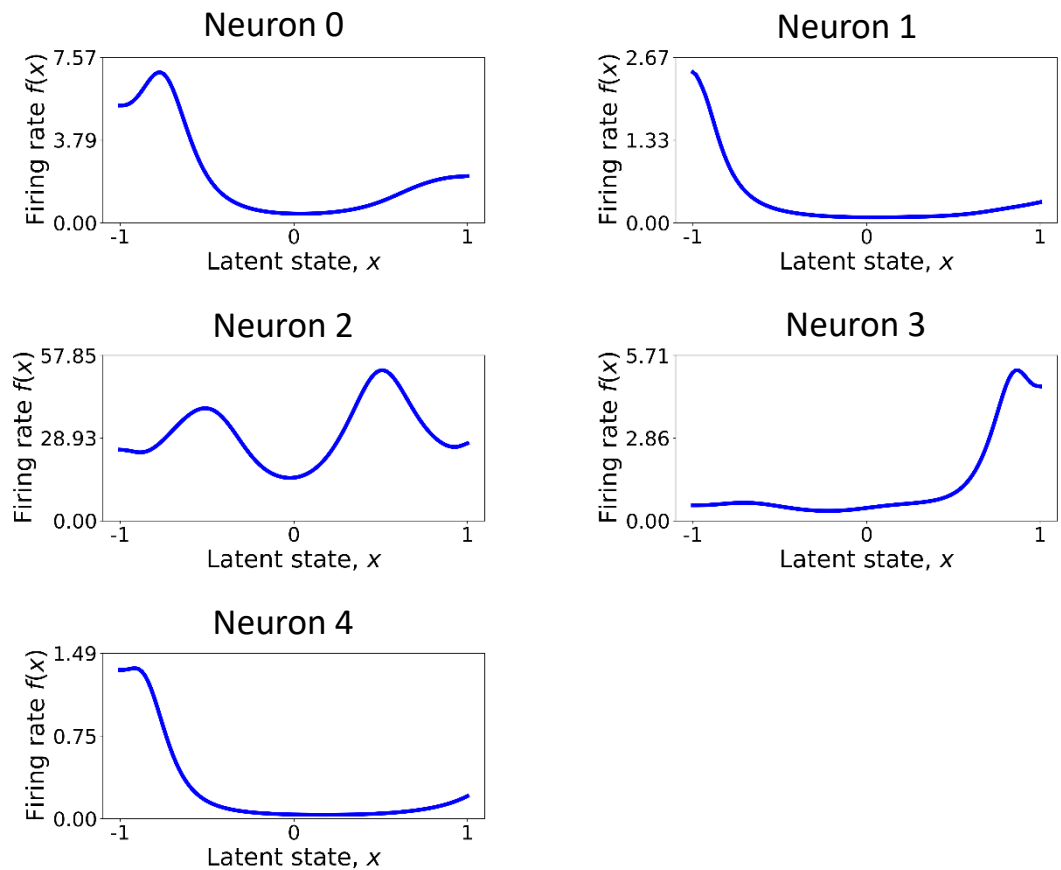
Two initial condition, one potential

No different input, loading in working memory

Potential and initial condition distributions

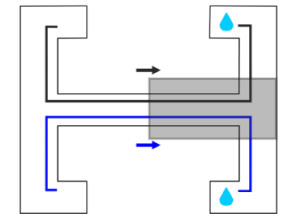
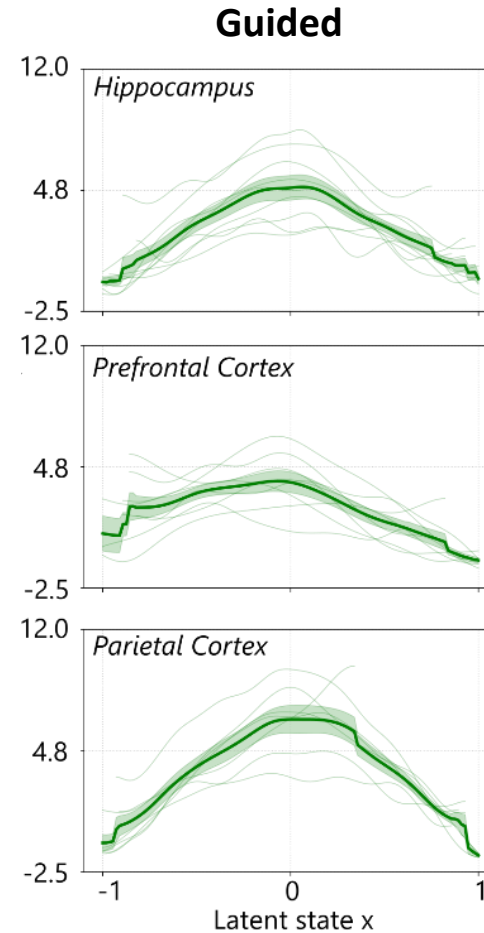
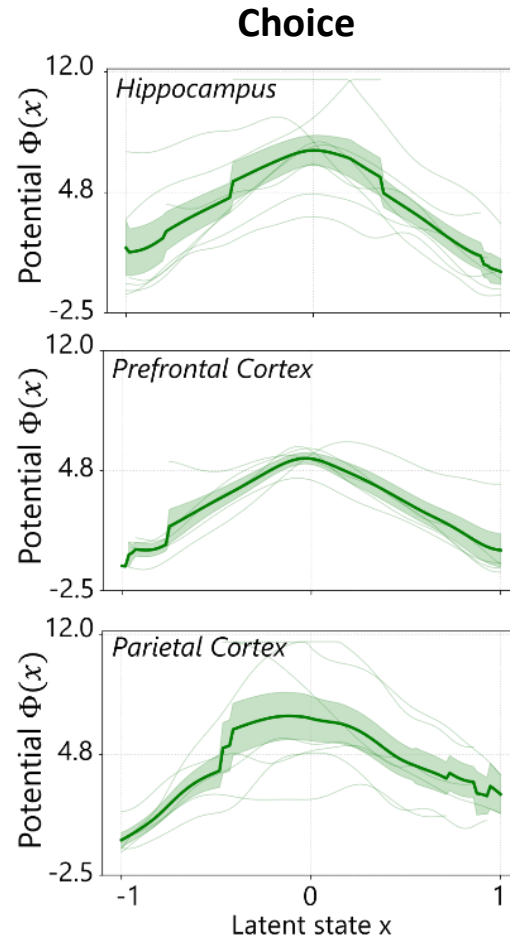
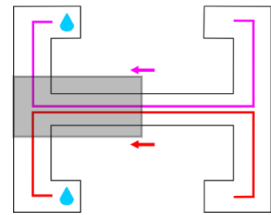


Tuning curves



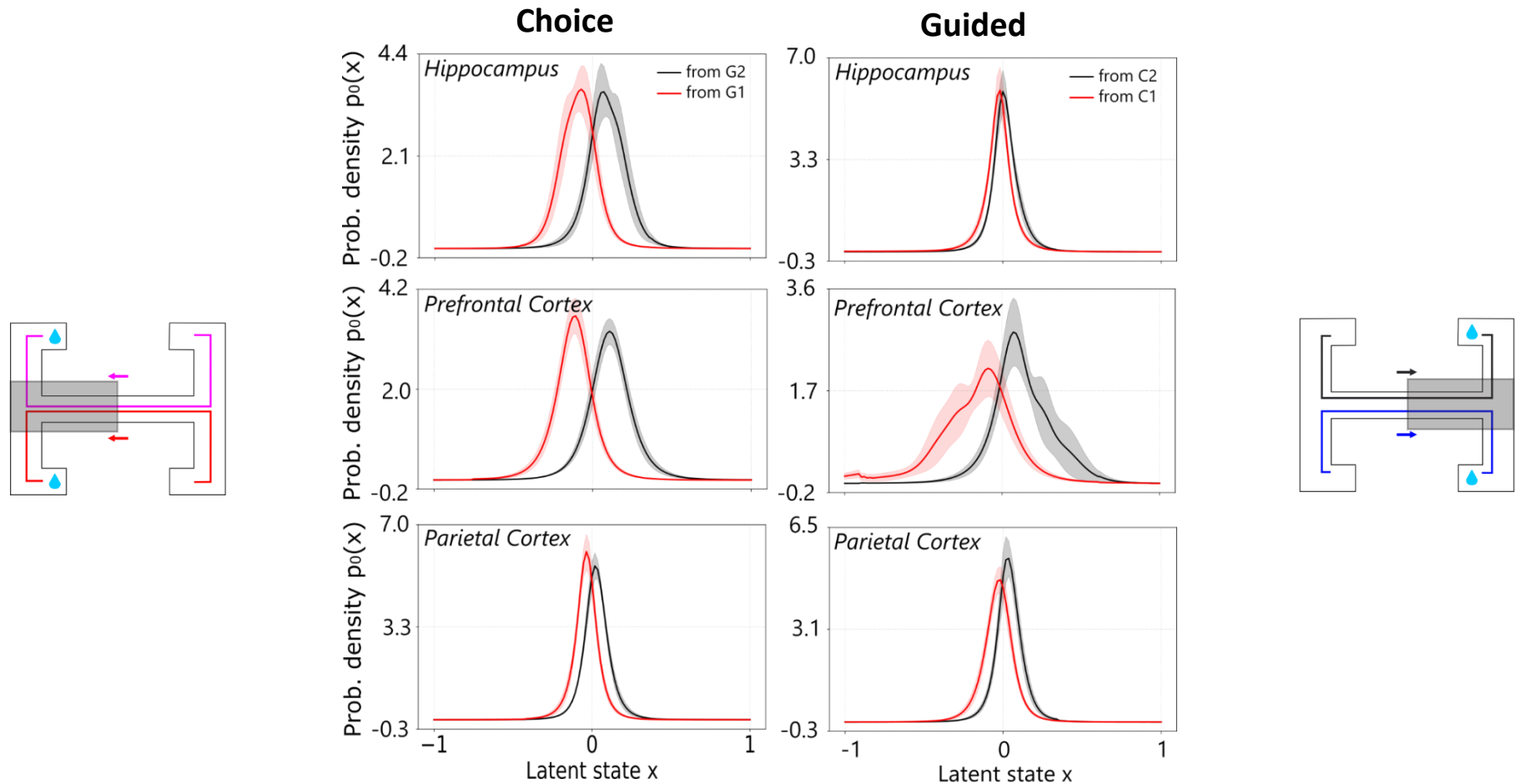
Potentials – dynamics

Aligned with respect to the mid point of the initial state distribution



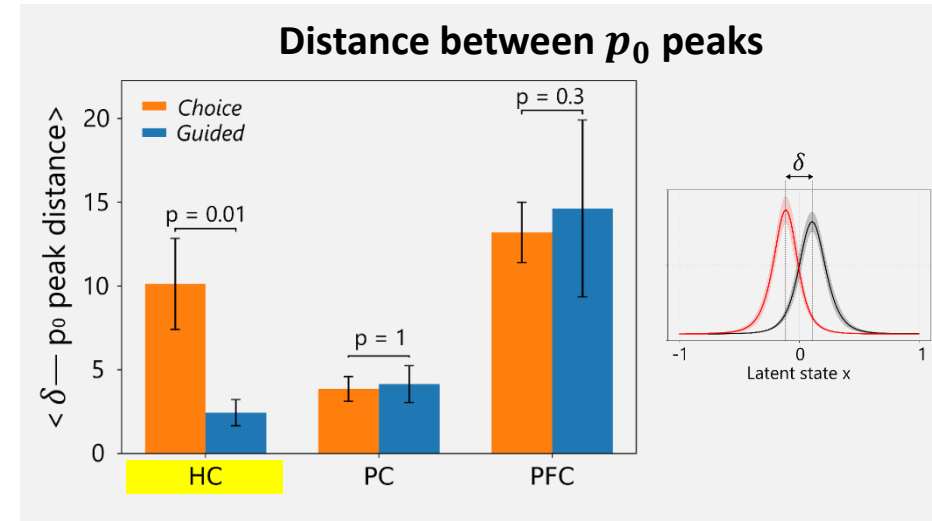
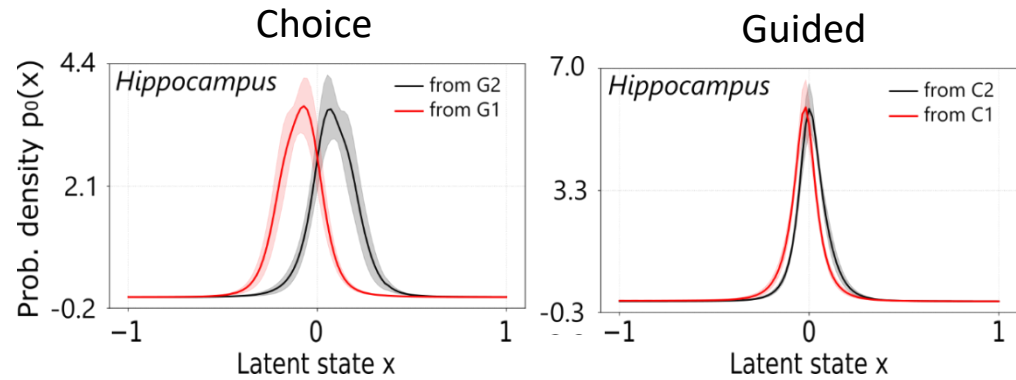
The **potential function $\Phi(x)$** shows a **bell-shaped profile** across several regions and animal groups.

Initial condition distributions - dynamics onset



p_0 capture the **state of the region** as the rat approaches choice / guided turns

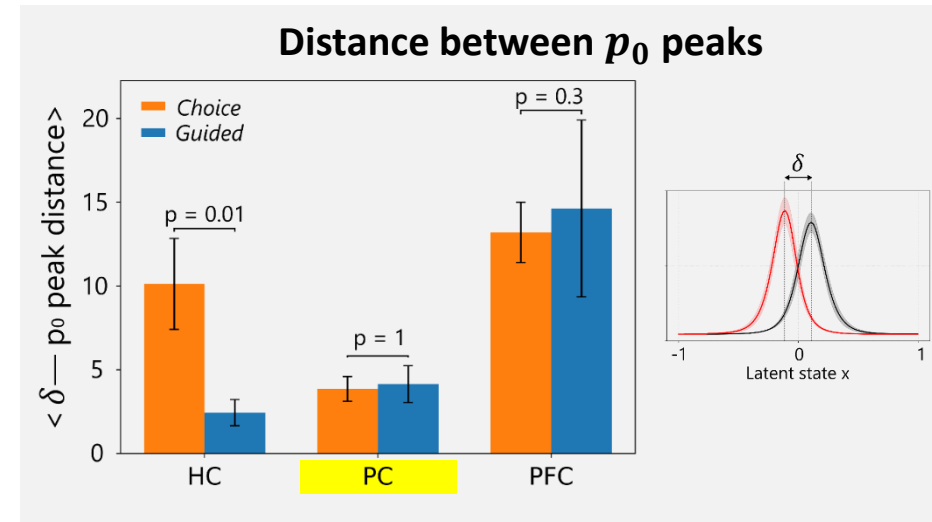
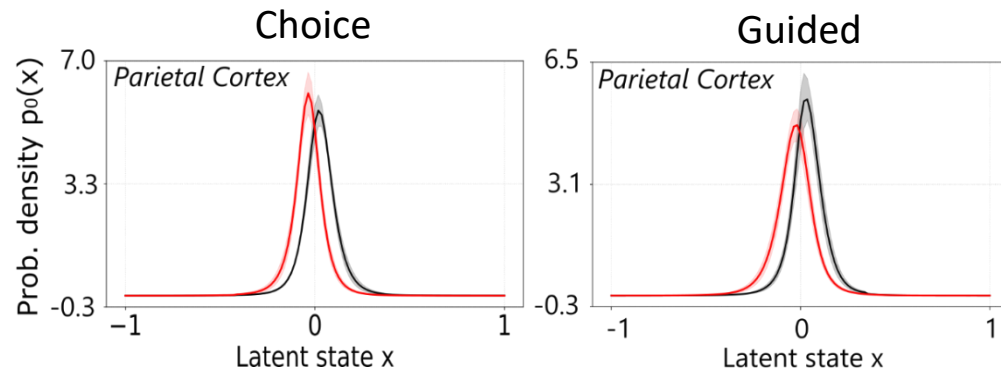
Latent dynamics onset comparison



➤ In the **HC**, the distance between the peaks differs when approaching choice or guided turns

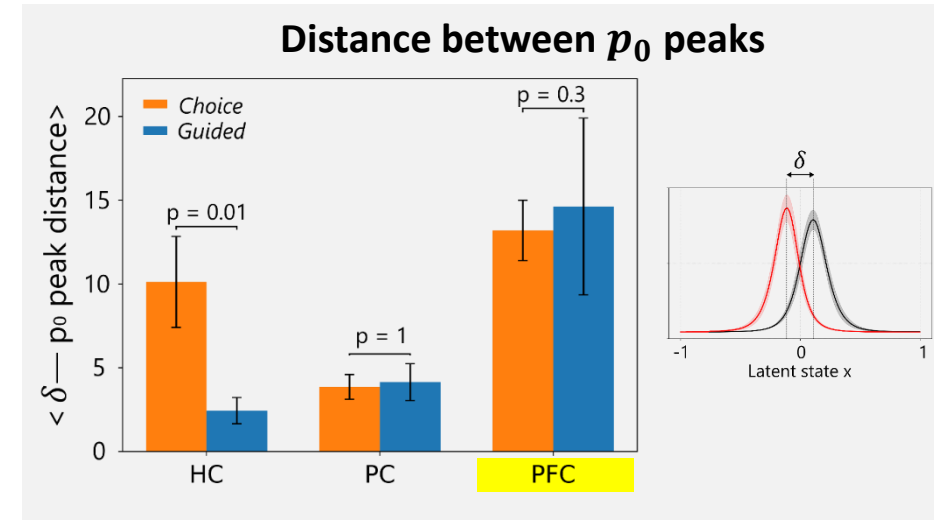
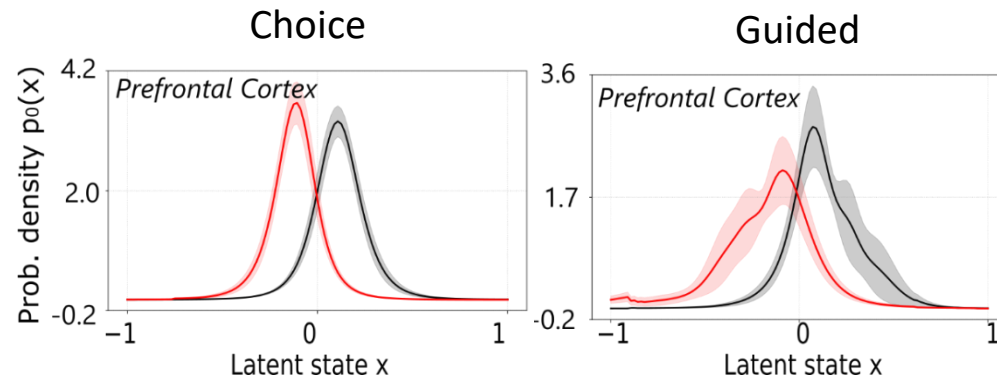
→ **HC encodes working-memory load**

Latent dynamics onset comparison



➤ **PC** approaches the choice/turns memoryless

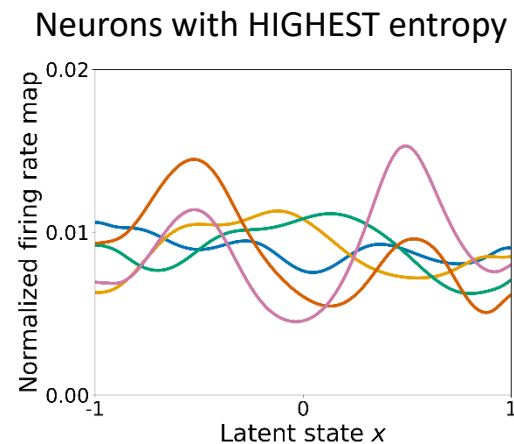
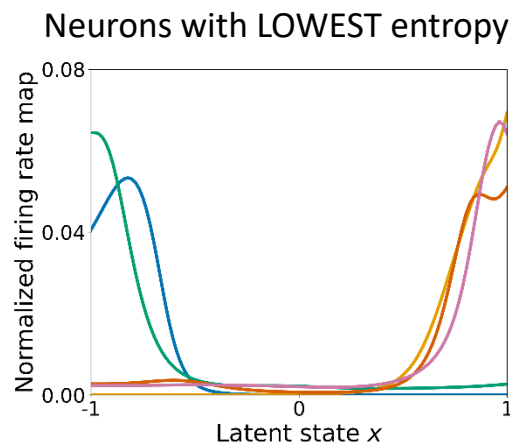
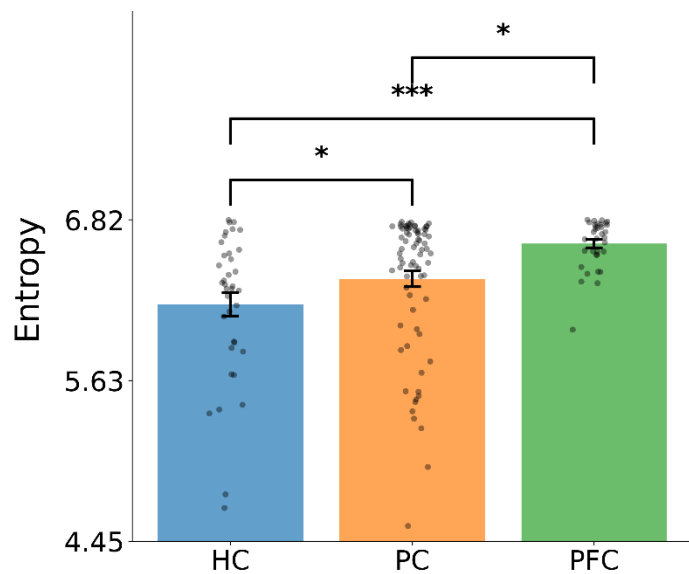
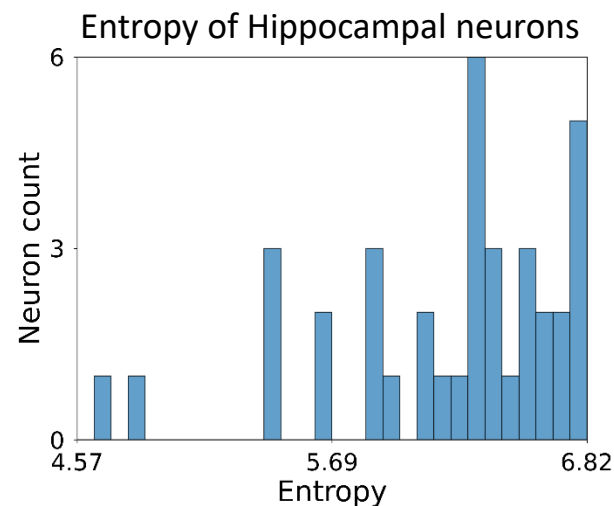
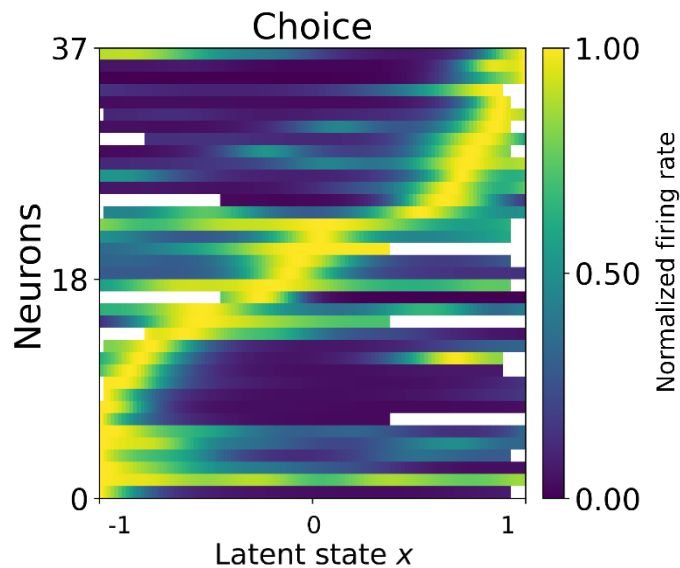
Latent dynamics onset comparison



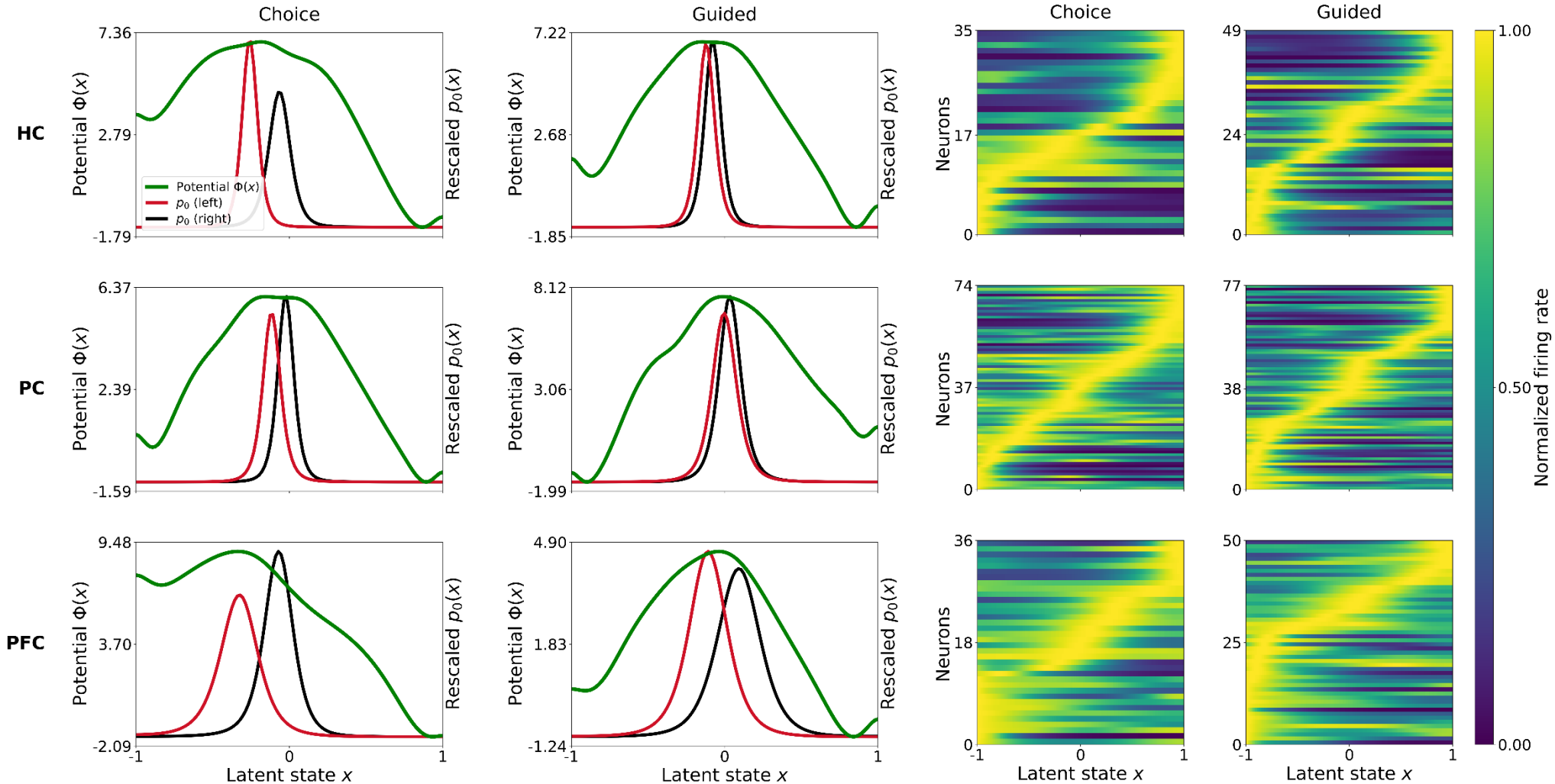
➤ **PFC** differentiates between left/right turns both during the choice and during guided turns

→ **PFC** encodes the current task state, not just task-relevant variables

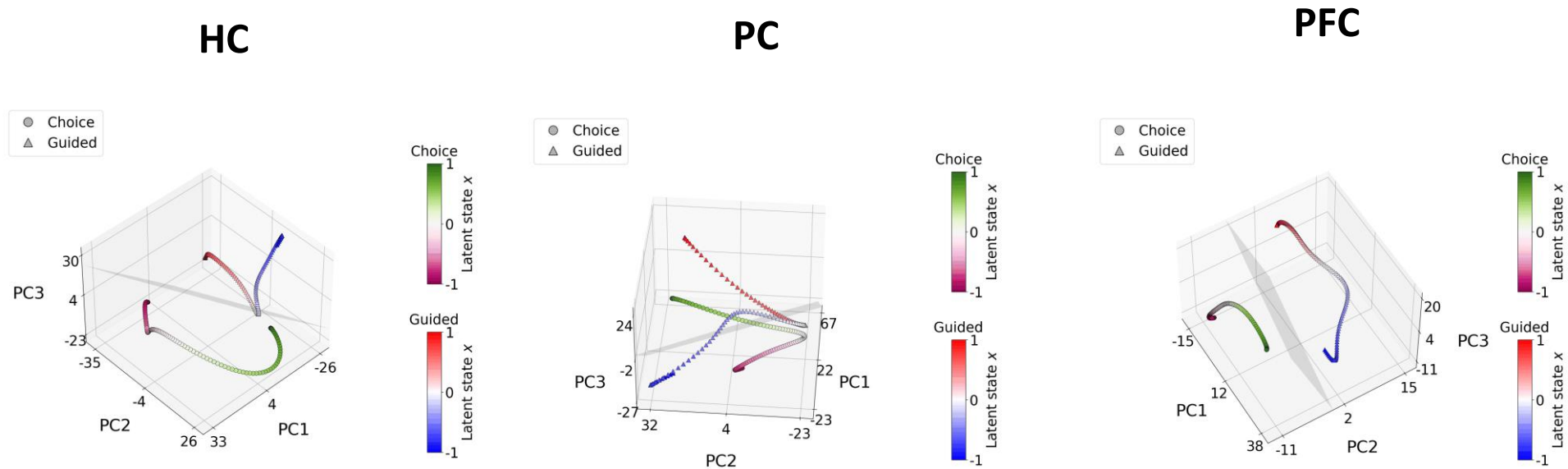
Coding distribution – sparsity analysis



Merged session results



Preliminary results – tuning curves geometry



Fraction of points crossing the plane

HC -> 4%

PC -> 46%

PFC -> 0%

The first 3 dominant tuning pattern
are discriminative between conditions
in HC and PFC but not in the PC

SVM hyperplane projected in the PCA 3D space



Preliminary conclusion

- The potential $\Phi(x)$, inferred independently for each area consistently shows a bell-shaped profile
- The initial-state distributions $p_0(x)$ are area-specific, revealing distinct roles in the latent dynamics.
- Single-neuron tuning to the latent variable shows a gradient of coding sparsity, from HC to PC to PFC
- Task conditions (choice vs guided) are linearly separable in the tuning geometry of HC and PFC, but not of PC

Different regions involved in the execution of a cognitive function are part of the same dynamical system and thus share the **same latent dynamics**.

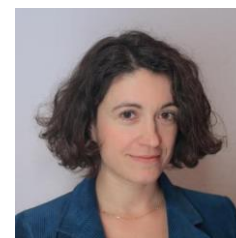
Yet, each region support this dynamics with **different coding schemes**.



Acknowledgements



The Brain Dynamics Lab



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Engel**



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W. Jones**

Questions?