High-order computations by neural population dynamics in the prefrontal cortex

The complex activity of neural populations in the Prefrontal Cortex (PFC) is a hallmark of high-order cognitive processes. Understanding how these rich dynamics emerge and give rise to advanced computations is central to neuroscience.

In the first part of the talk, I will describe modeling work that explains how contextual decision-making computations unfold dynamically in PFC circuits of monkeys performing a contextual integration task. We found that a whole class of simple linear dynamical systems models accurately captured the complexity of PFC responses. An extension of this model class with flexibility to capture non-linear temporal patterns performed comparably, suggesting that a linear approximation is sufficient to recapitulate the circuit dynamics in each context. Two contextual mechanisms were consistent with the data, which relied on either a change in recurrent dynamics or a direct re-balancing of inputs to integrate information selectively. Non-normal properties of the dynamics were leveraged to perform both slow and transient amplification of contextually relevant inputs. The integrated signals spanned a high-dimensional subspace and supported a computation that unfolded in two phases with different integration time-scales. This approach offers a principled framework to link the dynamics of neural populations to computation. However, it relies on assumptions about a key component: how the PFC dynamics are shaped by exogenous factors.

In the second part of the talk, I will address this issue by briefly discussing ongoing work that characterizes how external inputs into PFC drive different population responses. This is central to understanding how different brain areas communicate with PFC. To this end, we developed an inter-areal patterned microstimulation protocol in monkeys that allowed us to finely manipulate the activity of a neural population in one brain area while simultaneously recording the activity of a second population in a different area. We used our protocol to study how memory encoding in PFC is influenced by inter-hemispheric inputs. For this, we assessed the impact that different microstimulation patterns applied to the right-hemisphere PFC (RH-PFC) had on the contralateral PFC (LH-PFC) during a memory task. We found that the different patterns selectively affected PFC activity in different dimensions and biased performance and reaction times. This approach provides a causal tool to link brain activity and behavior at greater granularities, and paves the way towards data-driven models that explain how brain areas dynamically interact to produce computations.

Together, these two research efforts shed light into how the dynamics of neural populations in PFC are configured to generate complex behaviors.