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Inferring the dynamics of decision-making

During natural behavior, animals must continuously make decisions in a rapidly changing environment. Recent studies suggest that in such conditions, the brain simultaneously represents multiple potential actions that compete against each other within the same sensorimotor control circuits involved in execution. Here, I present analyses of neural spiking activity recorded from the cerebral cortex of monkeys, while they decided between two reaching movements based on a changing stimulus indicating which is more likely to be rewarded. We represent the state of the system as an evolving trajectory in a very high-dimensional space where each axis corresponds to the activity of one neuron, and use dimensionality reduction to project this to a 9-dimensional space capturing most of the variance in the data. We find that during the process of deliberation, the neural state evolves upon a roughly two-dimensional "decision manifold" defined by orthogonal components related to sensory evidence and the growing urge to respond. The moment of commitment occurs when the neural state falls off the edge of this manifold into one of two orthogonal attractors that lead to the initiation of the movements. We find qualitatively different decision manifolds in different brain regions. For example, the manifold in premotor cortex is significantly curved while in primary motor cortex it is remarkably linear. We conjecture that the premotor cortex implements a non-linear recurrent attractor system in which the decision is made, and this is read-out by the primary motor cortex to initiate the chosen action.