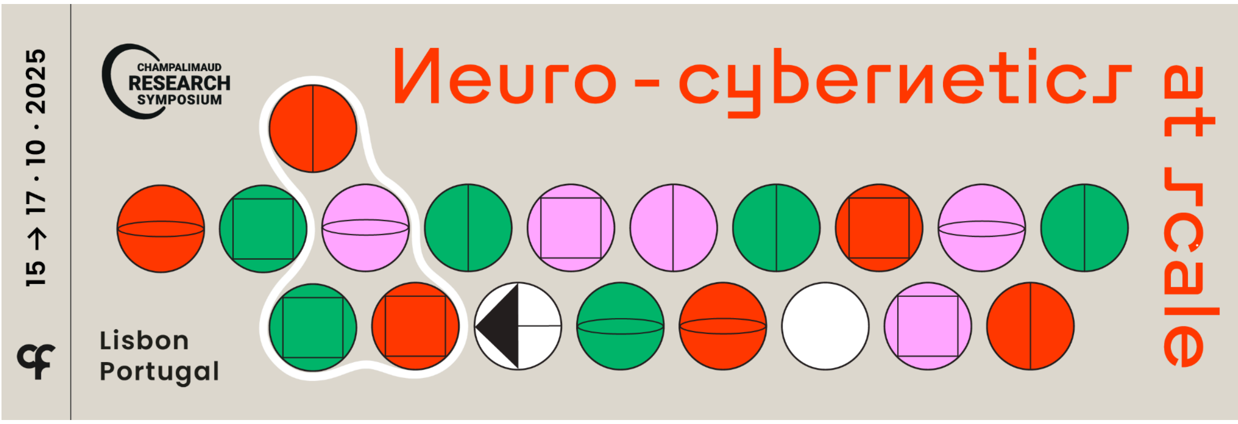

Deep Reinforcement Learning Sheds Light on Neural Manifold Dynamics in Motor Adaptation

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Animals can remarkably adapt their behavior to new conditions or in response to external perturbations. This capacity for motor adaptation is a fundamental aspect of motor control and has been the focus of extensive research. However, the mechanisms by which the brain achieves this ability and the neural computations underlying it remain a topic of debate. To explore these mechanisms, we simulate a virtual arm performing target-directed reaching movements, controlled by an artificial neural network trained via deep reinforcement learning. Following baseline training, in which the network generates hand trajectories closely matching empirical observations, we introduce systematic external perturbations that induce motor errors. The model subsequently adjusts its control strategies, recovering near-baseline performance. The resulting adaptation dynamics, including error correction and learning curves, mirror those observed in non-human primate experiments [1]. To examine the underlying neural representations, we apply dimensionality reduction techniques [2] to the network's activity during baseline, adaptation, and washout phases. We find that preparatory neural states organize into a ring-shaped manifold reflecting the geometry of the target space, which rotates during adaptation, consistent with observations in cortical preparatory activity [3]. Moreover, the post-washout manifold differs from its baseline counterpart, despite identical task demands, indicating a persistent neural signature of the perturbation, suggestive of a memory trace similar to what has been observed in primary motor cortex recordings [4]. These results highlight how reinforcement learning models can reproduce both behavioral and neural features of motor adaptation, offering a powerful framework for investigating the computational principles of sensorimotor learning [5].

computational neuroscience, motor adaptation, deep reinforcement learning, neural manifolds