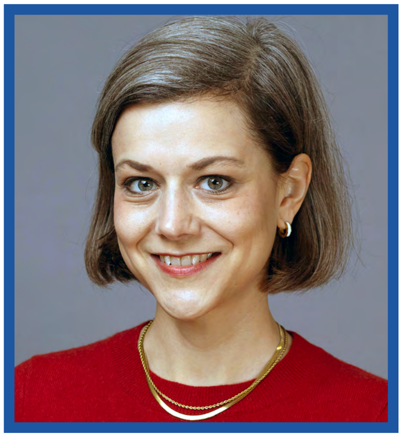
How Does the Brain Control the Movements of Our Arms?

April 28

Tuesday, 12:30 pm

Billings Building
Rosedale Room

SPEAKER:



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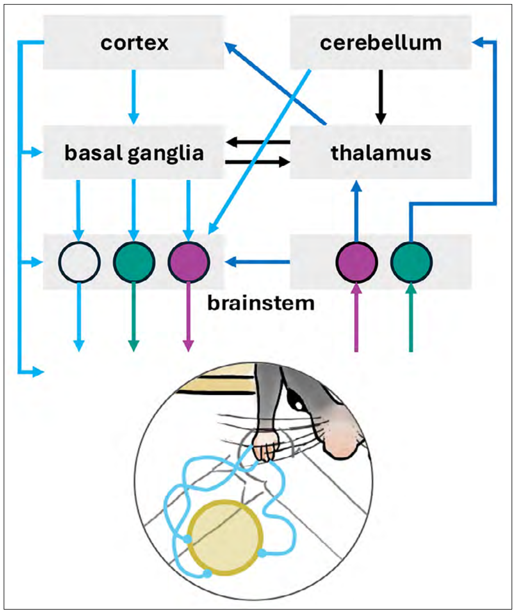
Abstract



Our brains constantly generate skilled movements with our arms, allowing us to interact with our environment. Yet how sensorimotor circuits learn, identify, and control the task-relevant aspects of these movements remains unclear. I will present work using a joystick-based reaching task in head-fixed mice, in which animals learn to reach to invisible spatial targets through exploratory forelimb movements. This ambiguous task has multiple potentially task-relevant aspects, such as initial reach direction and final endpoint location, which allows us to ask how the brain identifies, represents, and reinforces the aspects that matter for achieving a goal. Using probe tests with novel start positions, we find that individual mice preferentially learn either an endpoint-based or direction-based strategy, reflecting which task-relevant aspect is reinforced early in learning. The emergence of these strategies is related to the variability of initial movements and can be captured by model-free reinforcement learning agents. As mice learn this task, reaches become more refined in direction, tortuosity, speed, and targeting precision. We combine this behavioral framework with two-photon imaging, lesions, and pathway-specific perturbations to dissect the underlying circuitry. Initial reach direction is strongly encoded in the parafascicular thalamic nucleus, which projects to the dorsolateral striatum; lesioning this pathway prevents refinement of initial direction and impairs skill learning. In contrast, sensorimotor cortex provides rich information about ongoing hand position and influences which task-relevant strategy (direction- vs endpoint-based) is used, but is not required for successful acquisition of the task. Building on this platform, my lab investigates how different circuits identify and use task-relevant sensory feedback. Guided by the minimum intervention principle: the idea that feedback selectively corrects only those movement dimensions that are task-relevant, while allowing irrelevant variability to persist. By designing tasks that explicitly impose either feedforward- (preplanned control with minimal sensory feedback) or feedback control (requiring rich proprioceptive input and ongoing correction), we probe how the brain flexibly selects and regulates specific movement aspects. Using behavior combined with neural and muscle recordings, causal circuit manipulations, and computational analyses, our goal is to determine how descending and ascending pathways encode and reinforce task-relevant aspects of action, and how these mechanisms confer resilience and support recovery after nervous system injury or stroke.

Publications

1. Sibener LJ*, Mosberger AC*, Chen TX, Athalye VR, Murray JM, Costa RM (2025). Dissociable roles of distinct thalamic circuits in learning reaches to spatial targets. Nat Commun, doi: 10.1038 s41467-025-58143-4. PMID: 40140367, *co-first authors.

2. Mosberger AC, Sibener LJ, Chen TX, Rodrigues HFM, Hormigo R, Ingram J, Athalye VR, Tabachnik T, Wolpert DM, Murray JM, Costa RM (2024) Exploration biases how forelimb reaches to a spatial target are learned. Cell Reports, doi: 10.1016/j.celrep.2024.113958. PMID: 38520691.

3. Chung B, Zia M, Thomas K, Michaels JA, Jacob A, Pack A, Williams M, Nagapudi K, Teng LH, Arrambide E, Ouellette L, Oey N, Gibbs R, Anschutz P, Lu J, Wu Y, Kashefi M, Oya T, Kersten R, Mosberger AC, O'Connell S, Wang R, Marques H, Mendes AR, Lenschow C, Kondakath G, Kim JJ, Olson W, Quinn K, Perkins P, Gatto G, Thanawalla A, Coltman S, Kim T, Smith T, Binder-Markey B, Zaback M, Thompson CK, Giszter S, Person A, Goulding M, Azim E, Thakor N, O'Connor D, Trimmer B, Lima SQ, Carey M, Pandarinath C, Costa RM, Pruszynski JA, Bakir M, Sober SJ (2023) Myomatrix arrays for high-definition muscle recording. eLife, https://doi.org/10.7554/eLife.88551.1. PMID: 38113081.