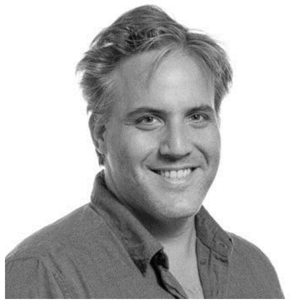
CRC 1451 - Project A06: Role of subcortical signals in selecting and updating motor plans

We studied the interactions between cerebellar signals and motor cortical circuity during motor adaptation task. Blocking cerebellar output using high-frequency stimulation successfully replicated the impairments found in cerebellar patients performing this task. Specifically, we found impaired adaptation and increased motor noise during cerebellar block. At the neural level, the cerebellar block led to a shift in the motor cortical preparatory activity and an increase in task-representation dimensionality. We concluded that cerebellar signals participate in shaping the motor cortical plan in a manner which is particularly important when adapting to a new environment. In the absence of these signals, cortical (voluntary) mechanisms are harnessed but they can only provide an insufficient and local compensation for the loss of cerebellar inputs.

Yifat Prut is a co-PI in the CRC Project A06. Her scientific work is focused on studying inter-areal interactions in the motor system and their contribution to adaptive motor output.

Sharon Israely is a former post-doc in the lab. He worked in A06 in the 1st funding period. His work focused on developing the model of cerebellar block during adaptive motor behavior.



Jonathan Kadmon is a computational neuroscientists who works on using computational and theoretical tools for studying neural networks including the cortical-cerebellar loops.

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nature communications

Article

https://doi.org/10.1038/s41467-025-57832-4

Cerebellar output shapes cortical preparatory activity during motor adaptation

Received: 4 August 2024

Accepted: 5 March 2025

Published online: 15 March 2025

Check for updates

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The cerebellum plays a key role in motor adaptation by driving trial-to-trial recalibration of movements based on previous errors. In primates, cortical correlates of adaptation are encoded already in the pre-movement motor plan, but these early cortical signals could be driven by a cerebellar-to-cortical information flow or evolve independently through intracortical mechanisms. To address this question, we trained female macaque monkeys to reach against a viscous force field (FF) while blocking cerebellar outflow. The cerebellar block led to impaired FF adaptation and a compensatory, re-aiming-like shift in motor cortical preparatory activity. In the null-field conditions, the cerebellar block altered neural preparatory activity by increasing task-representation dimensionality and impeding generalization. A computational model indicated that low-dimensional (cerebellar-like) feedback is sufficient to replicate these findings. We conclude that cerebellar signals carry task structure information that constrains the dimensionality of the cortical preparatory manifold and promotes generalization. In the absence of these signals, cortical mechanisms are harnessed to partially restore adaptation.

Motor adaptation is a remarkable mechanism utilized by all living beings to adjust to changes in both the external environment and the internal physiological state, an ability which supports routine behavior and long-term survival[1,2]. Numerous studies have shown that motor adaptation is achieved by tuning an internal model of the limbs[3,4]. In vertebrates, the cerebellum is considered to be the site where internal models are stored and is therefore responsible for the trial-by-trial recalibration of motor commands[5–8]. This assumption is supported by considerable data from animal models[9–11], imaging studies[12], and observations of cerebellar patients[13–18] who have difficulties adapting to novel environments. However, the mechanisms by which the cerebellar-based internal model gains access to motor output during sensorimotor adaptation remain unclear.

In the upper limb system of humans and nonhuman primates, cerebellar signals are predominantly relayed through the motor thalamus to the motor cortex[19], suggesting that adaptive motor behavior evolves through cerebellar-to-cortical interactions. Consistent with this view, large parts of the sensorimotor network, including the motor, premotor and somatosensory cortices[20–25] have been shown to correlate with motor learning as early as the planning phase of movements[22,26,27]. These early signals may have evolved through intracortical mechanisms to integrate with cerebellar signals when movements begin. Alternatively, adaptation-related cortical signals might

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