Article

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Behaviorally Selective Engagement of Short-Latency Effector Pathways by Motor Cortex

Highlights

- In mice, motor cortex is required for a trained forelimb task, but not walking
- Motor cortex activates short-latency effector pathways only during the trained task
- Distinct weighted sums of motor cortical firing patterns vary strongly in each task
- This change could permit motor cortex to engage short-latency pathways differentially

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In Brief

Miri et al. measured and perturbed motor cortical activity during simultaneous electromyography to reveal behavioral selectivity in the engagement of short-latency effector pathways by motor cortex. Changes in the correlation among output firing patterns appear to mediate this selectivity.

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Behaviorally Selective Engagement of Short-Latency Effector Pathways by Motor Cortex

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SUMMARY

Blocking motor cortical output with lesions or pharmacological inactivation has identified movements that require motor cortex. Yet, when and how motor cortex influences muscle activity during movement execution remains unresolved. We addressed this ambiguity using measurement and perturbation of motor cortical activity together with electromyography in mice during two forelimb movements that differ in their requirement for cortical involvement. Rapid optogenetic silencing and electrical stimulation indicated that short-latency pathways linking motor cortex with spinal motor neurons are selectively activated during one behavior. Analysis of motor cortical activity revealed a dramatic change between behaviors in the coordination of firing patterns across neurons that could account for this differential influence. Thus, our results suggest that changes in motor cortical output patterns enable a behaviorally selective engagement of short-latency effector pathways. The model of motor cortical influence implied by our findings helps reconcile previous observations on the function of motor cortex.

INTRODUCTION

Muscle contractions are readily evoked by stimulation of the motor cortex, indicating its capacity to drive movement (Leyton and Sherrington, 1917; Penfield and Boldrey, 1937; Van Acker et al., 2016). Although forms of movement that require motor cortical involvement have been identified, the influence of motor cortex on muscles during movement execution and its underlying neural mechanisms remain unresolved.

The behavioral consequences of inactivating motor cortex suggest that it plays a limited role in motor control. After lesions to motor cortex or the corticospinal tract, mammals exhibit persistent deficits in grasping movements but regain the ability to perform many motor behaviors (Alaverdashvili and Whishaw, 2008; Farr et al., 2006; Lawrence and Kuypers, 1968; Metz et al., 1998; Piecharka et al., 2005). Similarly, pharmacological inhibition of neural activity in the primary motor cortex of cats induces deficits in the ability to step over obstacles yet leaves basic treadmill walking essentially unaltered (Beloozerova and Sirota, 1993; Drew et al., 1996). Such findings have given rise to the view that motor cortex contributes to movements that require sensory-guided adaptation or that involve novel muscle activation patterns (Lemon, 1993; Shmuelof and Krakauer, 2011).

The specificity of deficits following inactivation, however, offers only limited insight into the influence of motor cortex during movement execution. The deficits that follow lesions or pharmacological inactivation change over time (Martin and Ghez, 1993; Passingham et al., 1983), implying the existence of compensatory mechanisms that modify motor control circuits (Nudo, 1999; Shadmehr and Krakauer, 2008) and obscure the normal role of motor cortical output. The specificity of inactivation deficits could reflect a role for motor cortex in driving muscle activity similarly across behaviors, with other motor areas compensating for the loss of motor cortical output during certain movements. Thus, it remains unclear whether deficit specificity reflects a selective motor cortical influence on the execution of particular movements.

Electrical recording and stimulation of motor cortex have not thus far revealed a behavioral selectivity in motor cortical influence that can account for the specificity of inactivation deficits. The firing patterns of motor cortical neurons correlate with

