

BOOSTING AND HINDERING ACTION IMITATION BY MODULATING SPIKE-TIMING DEPENDENT PLASTICITY

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Background: The action observation network (AON) engages premotor brain areas that influence the activity of the primary motor cortex (M1) during action perception (motor resonance) and the behavioral tendency to imitate the observed action. Yet, how ventral premotor (PMv) and supplementary motor area (SMA) pathways to M1 distinctly shape motor resonance and imitation remains unclear.

Aims: To investigate the plasticity and functional role of distinct premotor-M1 pathways in the phenomenon of motor resonance and automatic imitation through transcranial magnetic stimulation (TMS). We asked whether manipulating the strength of premotor-M1 pathways via TMS-induced Hebbian-like spike-timing dependent plasticity differentially (i) modulates motor resonance during action observation, and (ii) drives vs. controls automatic imitation.

Methods: We applied cortico-cortical paired associative stimulation (ccPAS) over PMv-M1 or SMA-M1 in healthy adults to strengthen or weaken premotor-M1 projections. In the first study, TMS over M1 was used to probe markers of motor resonance via electromyography and electroencephalography. In the second study, imitative behavior was assessed with imitation-inhibition and overt-imitation tasks. Drift diffusion modeling (DDM) decomposed latent processes underlying automatic imitation (starting point bias; drift rate).

Results: Strengthening PMv→M1 projections via ccPAS transiently increased electrophysiological markers of motor resonance in M1 and enhanced the automatic tendency to imitate observed actions; reversing stimulation order (M1→PMv) reduced automatic imitation. Strengthening SMA→M1 decreased automatic imitation and improved interference control in overt-imitation tasks. DDM showed a double dissociation: PMv→M1/M1→PMv ccPAS bidirectionally shifted the starting-point toward/away from an imitative response (bias), whereas SMA→M1 ccPAS selectively increased drift rate (context/rule integration).

Conclusions: By manipulating the strength of projections from premotor areas of the AON to M1, we demonstrate their malleability and causal role in action perception and imitation. PMv→M1 projections are pivotal for motor resonance and the automatic imitative bias, whereas SMA→M1 implements top-down gating by enhancing contextual evidence accumulation. These findings reveal a functionally dissociable organization within the AON, whereby distinct premotor-M1 pathways mediate complementary processes of action mirroring and control.

Keywords: Motor resonance, Automatic imitation, Action observation network, Cortico-cortical paired associative stimulation, Neuroplasticity

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