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Presentation Abstract

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Presentation Title: Motor cortical activity tracks the position of a brain-machine interface cursor

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Authors: ***S. D. STAVISKY**[1], J. C. KAO[2], P. NUYUJUKIAN[3,4], S. I. RYU[6], K. V. SHENOY[5,2,4];
[1]Neurosciences Program, [2]Electrical Engin., [3]Sch. of Med., [4]Bioengineering, [5]Neurobio., Stanford Univ., Stanford, CA; [6]Dept. of Neurosurg., Palo Alto Med. Fndn., Palo Alto, CA

Abstract: Brain-machine interfaces (BMIs) continue to move towards restoring movement to individuals with paralysis or limb loss. However, little is known about how the sensorimotor system incorporates BMIs into its motor control strategy. We tested whether a well-described property of arm control - that motor cortical activity is modulated by hand position (Caminiti et al. 1991) - also holds when a task is done with a BMI rather than with the arm. During arm reaches, hand position is linked to neural activity through mechanisms including proprioception, postural tonic output, visual feedback, and efference copy. Moving a cursor via BMI, without arm movements, minimizes the influence of proprioception and postural tone and reveals whether the cursor's position still affects neural activity.
Two macaques were implanted with multielectrode arrays in primary motor (M1) and premotor (PMd) cortex. They performed a 2D task in which a cursor either followed the monkey's fingertip (arm control) or was driven by a BMI that decoded multiunit activity into cursor velocity. During BMI use both arms were restrained. The monkey moved and held the cursor over a target appearing at a random location. We linearly regressed the multiunit firing rate during these hold epochs against hand or cursor position to measure how much neural variance was explained by position. In a representative dataset, during arm control the hand position explained significant variance ($p< .001$, shuffle test) on 118/161

movement-modulated channels ($R^2 \in [0.012, 0.531]$). In BMI control, cursor position explained significant variance on 77 channels ($R^2 \in [0.006, 0.196]$). Since the BMI controlled only cursor velocity, modulation of neural activity due to cursor position suggests that visual feedback and/or an internal model affect the motor system during BMI use. Further work must test if gaze differences contribute to this effect, but we note that our result holds in M1 and that prior studies found weak correlates of free gaze in PMd (Cisek & Kalaska 2002).
We further show that a decoder that accounts for neural modulation expected due to the current cursor position (Gilja et al. 2012) outperforms decoders that instead account for actual hand position (81% longer acquire times) or omit this step (14% longer acquire times). These results are consistent with a feedback controller view of motor cortex in which the BMI cursor is the task-relevant effector whose state is tracked by the sensorimotor system. It provides principled justification for applying an online control perspective to neural-control algorithm development and motivates future studies of how sensory feedback is incorporated into the neural state during BMI use.

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