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Neural activity in a simultaneous BCI & manual task

B. Lansdell^{1*}, I. Milovanovic^{2*}, A. Fairhall^{3,4}, E. Fetz^{3,4}, C. Moritz^{2,3,4}

*1. Applied Mathematics, 2. Rehabilitation Medicine, 3. Physiology and Biophysics, 4. Center for Sensorimotor Neural Engineering. University of Washington, Seattle, WA, USA. *these authors contributed equally*

*University of Washington. Lewis Hall #202, Box 353925, Seattle, WA 98195-3925 USA, E-mail: lansdell@uw.edu

Introduction: The cortical signals most directly associated with movement are observed in the primary motor cortex contra-lateral to the limb. In patients with lateralized cortical stroke, however, these signals are often lost. Brain-computer interfaces (BCI) may still provide a route to regaining lost motor function after stroke if neural control signals can be extracted from spared cortex. The presence of cortical neurons encoding ipsilateral wrist motion suggests this is possible [1]. Such an interface, however, demands that neural activity responsible for control of the unaffected limb is dissociated from activity responsible for BCI control. To determine the ability of neurons in motor cortex to successfully dissociate their output, we designed a dual control task in which a monkey simultaneously controlled a BCI while performing a motor task with their contra-lateral hand. By simultaneously observing neurons not directly used as a brain-control signal, we investigate to what extent the dissociation between hand movement and neural activity occurs at the individual neuron level.

Material, Methods and Results: One macaque nemestrina monkey was trained to perform a random target-pursuit motor task [2]. He began each day by controlling the cursor with isometric wrist torque (manual control, MC), then progressed to using the aggregate neural activity of two single units to control a cursor moving orthogonal to the units' preferred direction (brain-control, BC). Subsequently, he used the same neural activity to control the BCI in one dimension, while simultaneously using isometric wrist torque of the contralateral forelimb to control the cursor in a second dimension (Fig 1A). Within the sequence of tasks (MC->BC->DC->MC), we tracked a population of single, isolated units. To identify preferred torque output, tuning angle and strength, a linear encoding model was fit to each neuron as a function of torque.

Compared to the manual control task, units change both tuning strength ($p < 0.001$, two sided t-test) and preferred direction ($p < 0.001$; Fig 1B) when performing the brain control task rotated by 90 degrees. During this brain control task, tuning direction of the units directly controlling the BCI changed more than units not involved in BCI control ($p = 0.008$). During dual control, however, preferred direction changed similarly for both types of neurons ($p = 0.699$; Fig 1C).

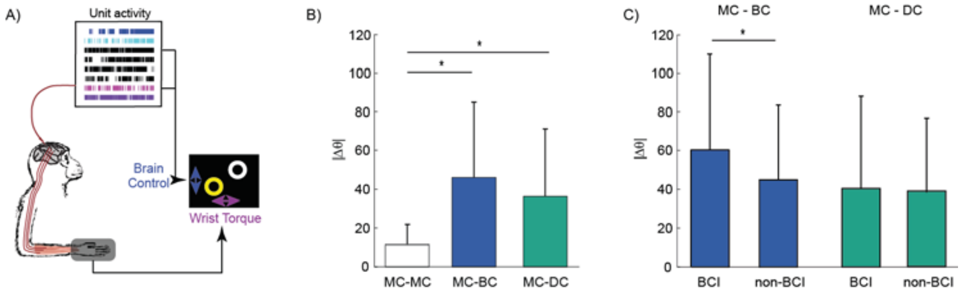

Figure 1 (A) *Dual control experimental setup.* ***(B)*** *Compared to the manual control task, the population of units changed their direction of tuning significantly during brain control ($p << 0.001$, t-test) and dual control ($p << 0.001$).* ***(C)*** *Units controlling the BCI change their preferred direction significantly more than non-BCI units during BC ($p = 0.008$). In the dual control task, however, BCI units did not change their preferred direction significantly more than non-BCI units ($p = 0.699$). All values are mean + standard deviation.*

Discussion: In both the brain control and dual control tasks we observe population-wide changes in tuning strength and angle. These population-wide changes may underlie the ability to select pairs of brain control neurons independent of their natural tuning properties [2]. Similar population-wide changes have been observed in brain control center out tasks [3]. The difference in BCI unit decoupling between brain and dual control (Fig 1C) may occur because the manual component of the dual control task constrains neural activity in such a way that the dissociation required of the dual control task can only be achieved at a population-level.

Significance: Our results describe how primary motor cortex accommodates a BCI task requiring explicit decoupling of neural activity from ongoing movement, as might be required for BCI use following stroke.

References

[1] Sharma M, Gaona C, Roland J, Anderson N, Freudenberg Z, Leuthardt EC. Ipsilateral directional encoding of joystick movements in human cortex. Conf Proc IEEE Eng Med Biol Soc. 2009:5502-5. DOI: 10.1109/IEMBS.2009.5334559

[2] Milovanovic I, Robinson R, Fetz EE, Moritz CT. Simultaneous and independent control of a brain-computer interface and contralateral limb movement. Brain-Computer Interfaces, DOI: 10.1080/2326263X.2015.1080961, 2015.

[3] Ganguly K, Dimitrov DF, Wallis JD, Carmena JM. Reversible large-scale modification of cortical networks during neuroprosthetic control. Nat Neurosci 14(5): 662-7, 2011.