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BCI Performance is Influenced by Motor Imagery Strategy and Somatotopic Constraints

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Introduction: Intracortical brain-computer interfaces (BCIs) enable people with paralysis to regain function by providing control of prosthetic limbs and computer systems [1]. BCI implants often target the "arm and hand" region of the primary motor cortex to extract neural activity patterns associated with reach and grasp. The first two participants in our study (P1 and P2) successfully used reach-related imagery to control both a computer cursor and a robotic prosthetic arm. However, the third participant (P3) has experienced unusual difficulty using reaching-related imagery for BCI control despite good signal quality. In contrast, P3 has achieved dexterous control in BCI tasks involving imagined movements of individual fingers on the hand [2]. Here we explored how motor imagery-based BCI performance is influenced by the location of intracortical arrays within motor cortex, specifically with respect to the hand-knob area.

Material, Methods, and Results: Intracortical data was recorded from two intracortical microelectrode arrays (Blackrock Microsystems, Inc.) while participants imagined performing simple hand, wrist, or shoulder movements. The electrode arrays were implanted in the anatomical hand knob region of motor cortex (M1) for P3, while P2 had one implant in the hand knob area and another more medial, where shoulder-related activity would be expected. Neural firing rates were estimated from the multiunit recordings on each channel and a channel was considered modulated for a specific movement if the mean firing rate during movement was significantly different from the baseline (resting) period.

Both participants had modulated activity during attempted hand, wrist, and shoulder movements, but a greater proportion of P2's significantly tuned channels were tuned to shoulder movements (45 out of 69 tuned channels, or 65%) compared to P3's (37 out of 131 tuned channels, or 28%). Conversely, P3 more grasp-modulated channels (23 out of 69, or 33%) displayed compared to P2 (88 out of 131, or 67%) displayed). Based on these results, we had P3 re-attempt a 2D cursor center-out task using a more distal, wrist-based imagery strategy (i.e. similar to controlling his wheelchair joystick) as compared to the previously unsuccessful strategy of using shoulder-based reaching movements. Immediately upon attempting this new imagery, P3 was able to successfully complete over 90% of center-out task trials, completing 54/56 trials of an 8-target version of the task with a click component modulated by imagined hand grasp within the same session. Offline, we trained a decoding model using only one of the arrays at a time to determine if array location impacted the type of motor imagery that could be decoded. When using reach imagery, removing information from the medial array (containing more shoulder-tuned channels in both participants) had a more negative impact on decoder performance than removing the lateral array for both participants, supporting the idea that natural somatotopy places constraints on the type of motor imagery that will lead to successful BCI control.

Discussion: Despite recent human studies showing that activity in the "arm and hand" region of motor cortex is modulated by movements ranging in origin from the mouth to the feet, we found evidence of somatotopic organization influencing BCI control. Based upon these fundings, we found that BCI performance could be improved by changing the motor imagery strategy used for control.

Significance: While additional training and practice may enable successful BCI control using a variety of imagery strategies, our results suggest that using somatotopically-congruent imagery can provide an immediate performance advantage.

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