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Coordinated arm movements are better represented in motor cortex than isolated movements

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Introduction: Natural reaching entails the coordinated movements of joints distributed over the entire upper limb – including the arm and hand. Furthermore, individual neurons in M1 carry “multiplexed” signals associated with the coordinated control of both hand and arm movements [1]. Despite this, brain-computer interface (BCI) decoders for restoring upper limb movement have been trained with isolated movements of the arm, wrist, and hand [2]. Decoders trained on (attempted) isolated movements may not generalize well to tasks requiring coordinated movements, yielding slower actions than those of able-bodied individuals [2]. Here, we show that calibration paradigms that include coordinated (imagined) movements of joints distributed across the entire limb yield decoders that can accommodate both coordinated and sequential movements.

Material, Methods and Results: A participant in an ongoing clinical trial for intracortical BCI control of a robotic prosthetic limb attempted to perform a sequential movement task and a simultaneous movement task. During the sequential movement task, the hand moved to a target, which then changed orientation. The wrist then rotated to accommodate the object’s new orientation. During the simultaneous movement task, the object was presented at a new location and orientation and the hand moved to the location and the wrist rotated appropriately in one smooth motion. We fit a linear 6D velocity encoding model to each set of neuronal responses and compared their ability to predict the responses obtained in the other set. We found that models fit to neural responses obtained during the simultaneous movement task could predict responses obtained during the sequential task but the converse was not true (Fig 1A). We also fit decoding models to each data set. Again, the simultaneous data yielded kinematic decoders that generalized to the sequential task, but the converse was not true (Fig 1B).

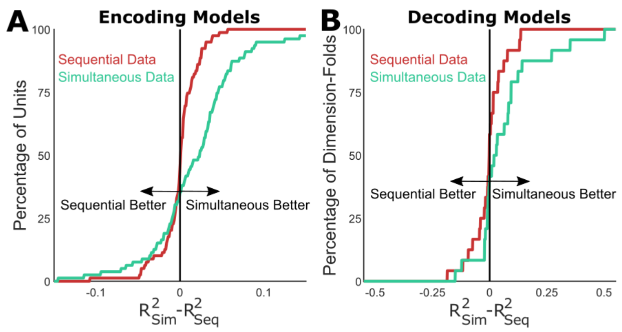

Figure 1. Coordinated movements evoke more recognizable activity in motor cortex. A) The linear encoding model explains evoked firing rates much better for most channels when fit on simultaneous movements. B) Similarly a decoder trained on simultaneous movements is much better at explaining simultaneous movements, and no worse at explaining sequential movements.

Discussion: When the BCI user attempted to move the wrist and arm at the same time, the evoked neural population yielded encoding and decoding models that generalized to actions where proximal limb and wrist moved sequentially. However, the inverse was not true, indicating that understanding the representation of coordinated movement is important to producing improved BCI decoders.

Significance: Training kinematic decoders on more naturalistic movements, which entail the coordination of joints distributed over the entire arm, will enable BCI users to perform more naturalistic movements and complete a wider variety of tasks.

References:

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