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The effect of artificially created sensory feedback on motor cortex activity during task performance

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Introduction: Intracortical microstimulation (ICMS) of the human somatosensory cortex can evoke localized sensations on a person's own paralyzed hand [1] and can significantly improve the control of a brain-controlled prosthetic arm [2]. Under normal circumstances, there is a direct interplay between naturally evoked touch and motor control; where ongoing sensory input modulates motor cortex activity, causing complex patterns of inhibitory and excitatory responses. Here, we investigate whether artificial touch (created via ICMS) could have a similar effect on motor cortex activity. If this is not the case, we expect that the neural communication of ICMS reflects a simple additive relation, where increasing total stimulation charge will have increasingly excitatory effects on motor cortex activity. If it is the case, we expect to observe more complex parameter-dependent effects, suggesting that artificial touch may engage circuits that are involved in the processing of natural touch.

Material, Methods and Results: All experiments were conducted with two participants that had tetraplegia and intracortical microelectrode arrays implanted in their somatosensory and motor cortices (Blackrock Microsystems, Inc.). First, we assessed the effects of ICMS on motor cortex activity. To do so, we presented a participant with ICMS trains of various amplitudes (40, 60, 80 μA) and frequencies (50, 100, 200 Hz), while they passively watched a movie. Next, we investigated the effect of ICMS while participants attempted a motor task. To create a realistic and engaging context for these repetitive experiments, participants observed a Guitar Hero-like game while receiving ICMS. The game provided intuitive visual cues synced to musical notes in a song to indicate the timing of specific motor actions (full grasp, or individual finger movements). In both experiments, we compared the firing activity in the motor cortex prior to and during ICMS. We found that higher stimulation amplitudes linearly increased the global population activity in the motor cortex. However, frequency had a different effect. Although 50 Hz stimulation had a largely excitatory effect on the motor cortex, stimulation at 200 Hz had a predominantly inhibitory effect, while 100 Hz stimulation had mixed effects depending on the electrode. The excitatory effect of stimulation at 50 Hz was clearly visible during both motor task performance and at rest. Despite these prominent effects on motor cortex activity, preliminary results from one participant show that offline decoding of three individual fingers is possible (89% accuracy) in the presence of 50 Hz ICMS.

Discussion: Our results show that ICMS can have stimulus-dependent effects on motor cortex activity. We aim to elucidate these effects in future research in which we provide (in)congruent ICMS feedback while participants play a bidirectional brain-controlled version of our Guitar Hero game.

Significance: We show that ICMS cannot only be used to create an artificial sense of touch during motor control but can also modulate motor cortex activity in a stimulus-dependent way, similar to natural touch.

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