

Title: Volitional control of single-channel spike firing rates for bridging cortical areas with bidirectional brain-machine interfaces

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Abstract: Brain injury can produce deficits through disconnection of cortical areas. One possible treatment is to bridge damaged connections by recording from one area and delivering contingent stimulation to another with bidirectional brain-machine interfaces (BMI). Such bidirectional BMIs can not only provide a bridge between cortical areas, but also achieve a closed-loop brain stimulation system in which a subject can regulate stimulation parameters in one area by controlling neural activity in another area. This can provide an easier way to calibrate stimulation parameters in BMIs, investigate connections between stimulation patterns and evoked sensations, and explore neural plasticity induced by new connections between brain areas. For these reasons, we are interested in implementing a bidirectional BMI in human patients.

In this study, we examined anterior intraparietal (AIP) and ventral premotor area (PMv) as recording sites, and hand and arm regions of primary somatosensory cortex (S1) as stimulation sites. These regions have the advantage that the subject can evoke sensation from his hands or arms as a result of controlling neural activity in the grasp-related areas. A 33-year-old tetraplegic subject in this study, FG, was implanted with Neuroport arrays (Blackrock Microsystems) in these areas. We looked for units in AIP and PMv that were modulated during imagined tasks, like grasping, scratching, rotating the arm, and counting. We then selected a channel that was tuned to a certain imagery, and graphically showed the spike firing rates from that channel to FG. We asked FG to increase or decrease the displayed firing rate, to evaluate volitional control on the neural activity. Demonstrating such control over single-channel firing rates is an important first step toward connecting brain areas and regulating stimulation in one site based on the activity in another.

We found a significant number of units in AIP and PMv tuned to different mental tasks. Some were tuned to multiple actions, often when the actions were similar, as in scratching and grasping. FG was able to identify appropriate mental imagery to increase or decrease the firing rate measured from the selected channel, and could control such activity volitionally. In most cases, FG was able to increase or decrease the firing rate to the target level in 2 seconds. FG could also change the firing rate and hold it within a target range for a given duration. These results show that FG had reliable, volitional control over single-channel spike firing rates, and further demonstrate the potential for self-calibration and optimization of stimulation parameters and patterns in S1 to produce more intuitive sensation.