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Predicting Forelimb Muscle Activity from Corticospinal Signals in Rats

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Introduction: Brain-computer interfaces have the potential to improve the quality of life in high level spinal cord injury (SCI) patients by restoring their functions lost due to injury. Historically, extracting kinematic parameters from neuronal spiking activity has been the primary method in brain-computer interfaces. Recently, our group has proposed accessing the spinal cord descending tracts to extract the movement related volitional signals as an alternative method. We have reported the ability to reconstruct forelimb kinematics, such as hand velocity and elbow angle, as well as the forelimb isometric forces using the neural signals recorded from the rat corticospinal tract (CST). In this study, we present that the forearm electromyographic (EMG) signals recorded during a reach-and-pull task can be predicted from the CST signals.

Material, Methods and Results: A flexible multi-electrode array (MEA) was custom-designed for this study (NeuroNexus, MI). The array consisted of 27 platinum contacts with 25µm diameter. The contact impedances were lowered by electrochemically depositing PEDOT:TFB [1]. Two Long Evans rats were implanted with MEAs. The arrays were inserted down vertically along the middle of the cord into the dorsal column at C4 level [2]. Teflon coated 25µm diameter stainless steel wires (A-M Systems) were used as EMG electrodes. Four pairs of electrodes (with ~5mm separation between tips) were glued epimysially on distal forelimb flexor and extensor muscles, biceps, and triceps. In order to obtain forelimb specific CST and EMG recordings, the rats were placed inside a plexi-glass box and trained to reach through a 3 by 1 cm vertical window to pull on a metal bar that was attached to a force transducer. Signals were recorded only when the pulling force exceeded a certain threshold. Neural and EMG signals were amplified and transmitted by a 64-channel wireless amplifier (TBSI Systems, NC) at a 16kHz sampling frequency. Multi-unit activity (MUA) was extracted by band-pass filtering the spinal cord signals between 200-2500 Hz in Matlab (Mathworks, MA). Muscle activities were band-pass filtered between 10-1500 Hz. Both MUA and EMG signals were rectified and low-pass filtered at 4 Hz before being fed into the prediction algorithm.

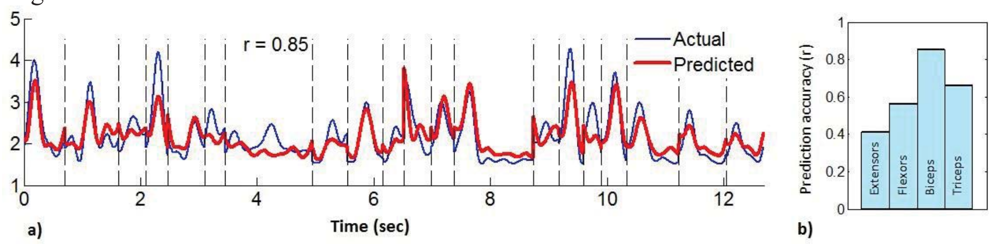

Figure 1. *Actual (blue) and predicted (red) biceps EMG signals recorded during isometric pull task (a). Prediction accuracies of all four EMG signals that belong to the same recording session (b).*

EMGs were predicted using linear regression. The dataset consisted of 80 trials; 75% of them used as the training set while 25% as the test set. As a representative image from one session, figure 1 compares the linear prediction of biceps activity to the actual recorded signal in multiple trials separated by dash lines. Figure 2 depicts the prediction accuracies for all the muscle activities that belong to the same session. The prediction accuracy is measured as the Pearson's correlation coefficient (r) between the predicted and actual signals.

Discussion: The results show that forearm muscle activities can be predicted from descending signals recorded from the spinal cord in rats. We achieved prediction accuracies as high as 0.85 for the biceps EMG. Although the accuracies for other muscles were not as good, this can be justified by the fact that during the isometric pull task biceps are more active than the other three muscles. These initial findings are encouraging, which warrants verification of results in a larger set of animals.

Significance: Since the muscle activity is represented in multiple regions in the brain, tapping into descending signals at the spinal level may provide more volitional information from a relatively smaller implant area. Predicted EMG signals can provide a means to control actuators in a biologically realistic manner.

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