SUNY DOWNSTATE Medical Center

Joe Francis Lab

Relationship between neural activity in multiple sensorimotor cortices and force related variables during primate reaching movements

Pratik Y. Chhatbar[1,2], Mulugeta Semework[1,3], Joseph T. Francis[1,2,3,4]

[1]Department of Physiology and Pharmacology, [2]Graduate Program in Biomedical Engineering, [3]Graduate Program in Neurobiology and Behavior,
[4]The Robert Furchgott Center for Neural and Behavioral Science, SUNY Downstate Medical Center, Brooklyn, NY

NEUROSCIENCE 2009

181.21, CC46

Introduction

We use different forces to manipulate objects with different inertial properties. Controlling kinematic variables using brain activity has been well established, but less is known about the neural encoding of the force-related variables. In this poster, we will compare the simple linear relationships between simultaneously recorded dorsal premotor (PMd), primary motor (M1) and area 2 of primary somatosensory (S1) cortical activity and different kinematic and dynamic variables and muscle activation patterns.

Methods

Surgical Implantation

Microelectrode implants were performed on Isoflurane-anesthetized monkey in a sterile surgical environment. The monkey was implanted with three Utah microelectrode arrays (MEA, 1.5 mm length 10x10 microelectrodes per array, inter-electrode spacing ~400 μm, Blackrock Microsystems, Salt Lake City, UT). Location of the implant was determined by intra-operative electrophysiology in S1 region for shoulder area and contiguous M1 and PMd regions were selected for implantation. S1 region was implanted with Iridium Oxide (IrOx) coated MEA while M1 and PMd were implanted with regular Platinum (Pt) MEA.

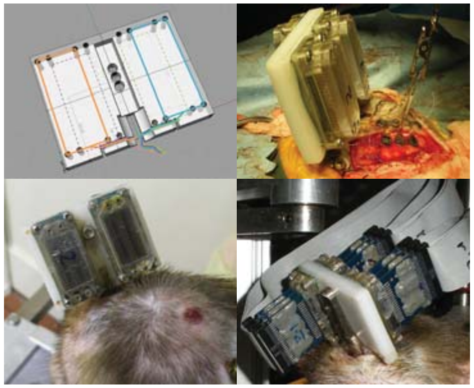
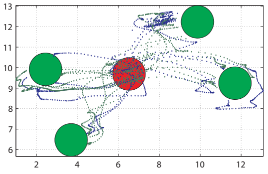
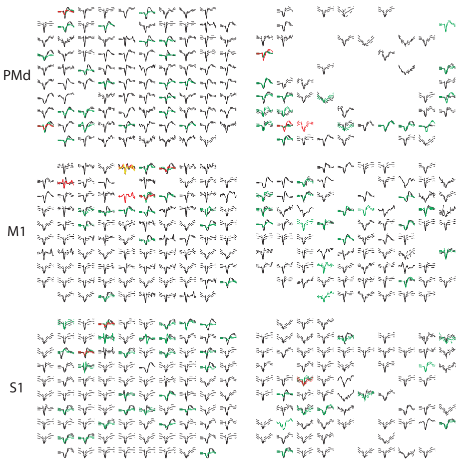


Fig 1: (top left) nesting platform (NP); (top right) implant in sensorimotor regions; (bottom left) 6-months after implant; (bottom right) connectors with head-stages plugged in

Neuronal and behavioral recordings

All recordings were made on awake, head-restrained animal sitting on a primate chair. The monkey was well-trained to work on delayed center-out reaching task under continuum of different force-fields with KinARM (BKin Technologies, Kingston, ON) robotic manipulandum on which the right hand is lightly restrained. The neural, EMG and behavioral recordings were made with three externally synced 128-channel Multichannel Acquisition Processor units (Plexon Inc, Dallas, TX). The figure on the right shows part of sample movement trajectory of the task (blue- low, green- high resistive field.)





1 month post- implant

6 month post- implant

Fig 2: Typical waveforms

Analysis

Multiple linear regression method was used to do the predictions of the different kinematic and dynamic variables. Selection of units, if done, was based on changes in the neuronal activity pattern around the onset of movement. Kinematic data was smoothened by 6th order 3 db double-pass filter with frequency cut-off at 10 Hz. Absolute values of EMGs were used. Of around 8 to 10 minutes long data file, first 80% of the data was used to train the model and see the fit and last 20% to do predictions. Correlation coefficients of fits and predictions against actual data were compared for different variables against different cortical regions and also all regions together. The interactions between neurons were checked using Granger's causality test and are shown in figure 6.

Results

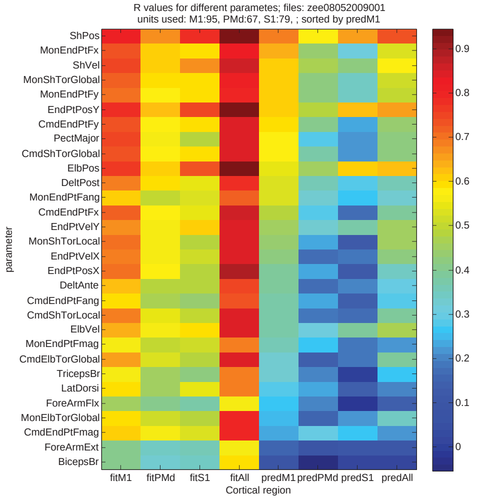


Fig 3: Example of correlation coefficients of fits and predictions for different cortical regions and when combined.

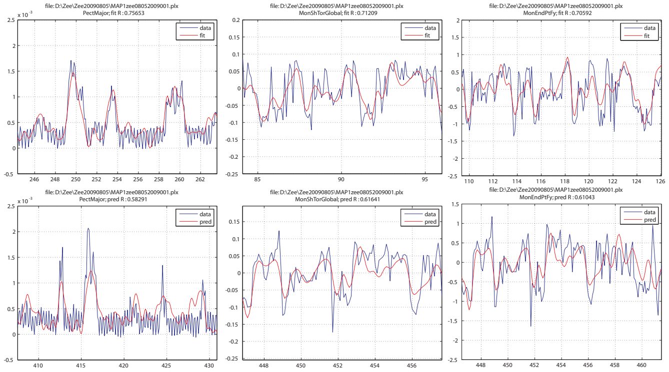


Fig 4: Example of fits (top) and predictions (bottom) for pectoralis major EMG activity (left), end-point force in y-direction (right) and shoulder torque values (middle)

***Key to figures 3 and 4:** Sh-shoulder; Elb-elbow; Pos-position; Vel-velocity; Mon-monkey; Cmd-applied by motor; Pt-point; Tor-torque; F-force; X-direction x; Y-direction y; Pect-pectoralis; Delt-deltoid; Ante-anterior; Post-posterior; Ang-angle; Br-brachii; Lat-latissimus; Flx-flexor; Ext-extensor; Mag-magnitude; M1-primary motor; S1-primary somatosensory; PMd - dorsal pre-motor area*

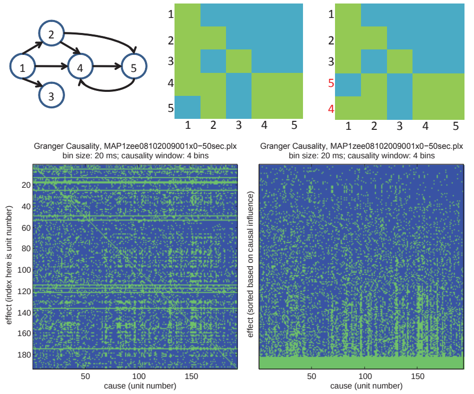


Fig 5: Example of 'Granger' Causality between pairs of units for 80 ms window on 20 ms bin size of neuronal spike data (bottom row). Causal pairs are shown as green and are sorted by rank order (bottom right), so that the units that are least affected by firing of the other 'cause' units sit on the higher rows, and indexed lower number under 'effect'. A simple explanatory figure is shown on the top row. Since neuron 4 is getting the most inputs, it has lowest rank order. So, it is sorted below the neuron that has less number of inputs (neuron 5). The other neurons 1,2 and 3 didn't need sorting as they are already ordered as per their number of inputs.

Future Directions

Future selection of relevant units will be based on multiple regression analysis methods mainly considering the leverage and multicollinearity principles and also including the covariance and causality maps within and across different cortical regions. We are on our way to implement real-time, closed-loop, force-based brain machine interface (BMI) which can selectively use any or all of the available neural signals. It would be interesting to compare these 'offline' results of predictions with the 'online' interactions of the animal while controlling such a BMI.

Selected References

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This work is supported by National Academies Keck Futures Initiative NAKFI SP09 and NYS Department of Health SCIRBs # C022048