

The relationship between the activity of neurons recorded simultaneously in primary motor cortex

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Accurate decoding of the neural activity in the primary motor cortex (M1) could be very useful for brain machine interface applications such as computer displays or prosthetic limbs. In this study we examined information coding in M1 neurons to elucidate the relationship between the activity of M1 neurons recorded from a 100 electrode array implanted in the proximal arm area of macaque monkey, during an 8-out reaching task, using the Stevenson et al. (2011). data set from Database for Reaching Experiments and Models (DREAM).

As expected, the individual M1 neurons exhibited cosine tuning. We implemented an offline decoding algorithm using Kalman Filter which models the motion of the hand and the probabilistic relationship between this motion and the mean firing rates of the cells in 20ms bins. We have shown that the Kalman Filter was able to accurately predict the actual trajectories that the monkey made. Next we investigated how the activity of pairs of neurons were correlated with each other. We calculated a correlation coefficient for number of spikes pairs of neurons fired during the course of the arm. We found that the activity of neurons with similar preferred direction was positively correlated, whereas those with opposite tuning were negatively correlated (Fig. 1). In contrast, the activity of these neurons prior to the go cue was poorly correlated.

As our Kalman filter model shows, the spike trains recorded from M1 are a usable control signal, suggesting that control information is coded in the spike train signal. We hypothesized that the information content of spike trains recorded from trials where movement was towards a target near the preferred direction would differ from the information content of spike trains recorded from trials where movement was in the opposite direction. Approximate entropy (Pincus, 1991) was used to characterize each spike train. Independent t-tests showed no significant difference between the entropy of the spike trains from movement near the preferred direction as compared to movement in the opposite direction, and a Kolmogorov-Smirnov goodness-of-fit test also found no significant difference between the approximate entropy distributions for the two conditions. A subset of 13 neurons were selected with high directional tuning, and even for this subpopulation of highly tuned neurons, neither independent ttests nor Kolmogorov-Smirnov goodness-of-fit test significant differences between approximate entropy for the two directions. Approximate entropy was not sensitive to the differences in information content measured in single neurons, perhaps because population coding requires interactions of multiple neurons. Thus information measures for pairs of neurons may be expected to be more informative than those for single neurons.

Finally, we investigated the functional connectivity of neurons in M1 using information theory measures. The components of the brain interact in a complex, multilevel and nonlinear way. Understanding cortical motor control function requires knowledge of how the neurons interact. We found that immediately after target onset (0 to 600 ms), neurons had a higher mutual information index when movements were made in their non-preferred direction. These results suggest that when reaches are made in a neuron's preferred direction they share less information with neurons that have similar tuning properties. As such, neurons with similar tuning provide more information about the reach movement when it is being made in the direction they are tuned for.

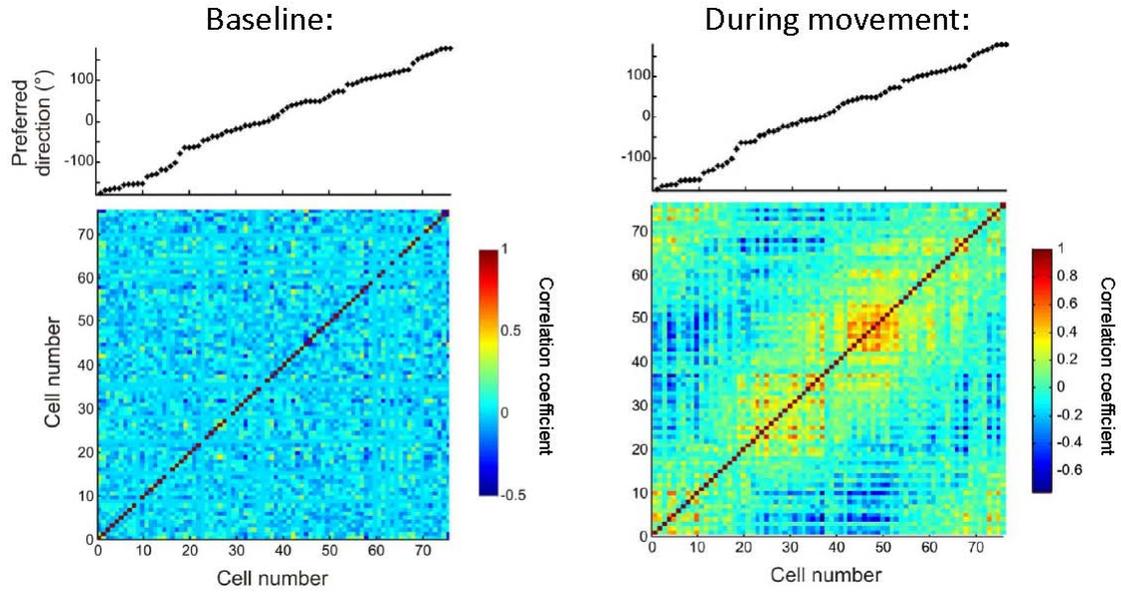


Figure 1: Correlation coefficient calculated for all of the pairs of neurons during baseline conditions (left panel) and reach movements (right panel). Neurons are ordered according to their preferred direction. We found no correlation during baseline conditions. In contrast, during the reach movement, the activity of neurons with similar preferred direction was positively correlated whereas those with opposite tuning were negatively correlated.

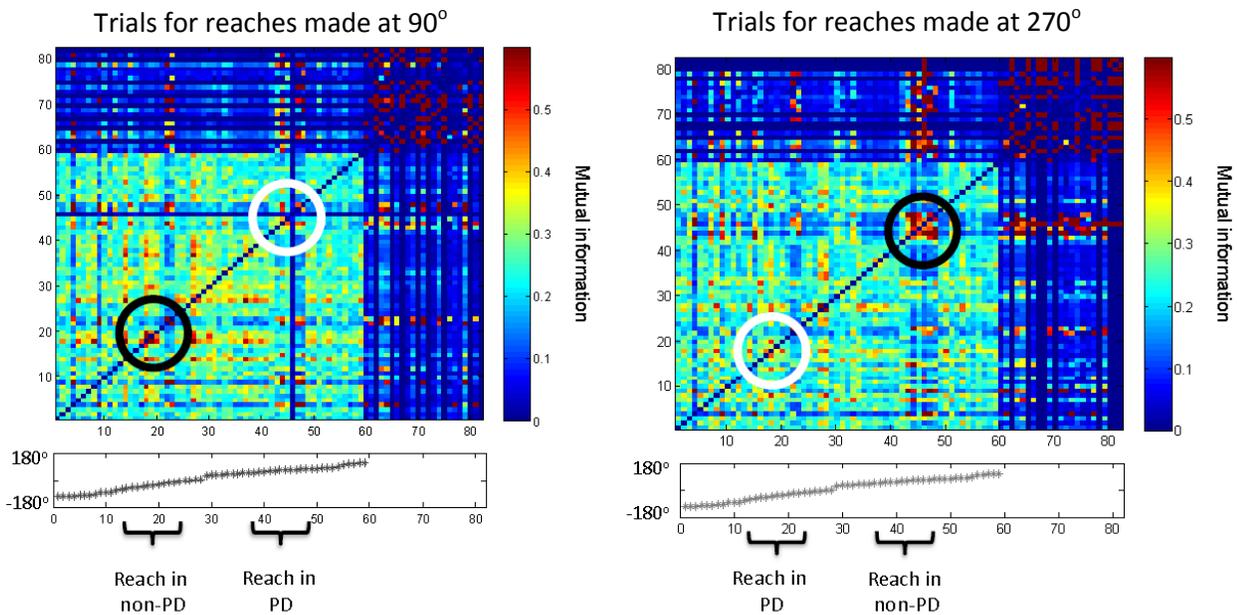


Figure 2: Mutual information calculated for all of the pairs of neurons for 600ms after cue onset. Neurons are ordered according to their preferred direction. We found that neurons with similar preferred direction shared more information when movements were made in their non-preferred direction.