The constraints of neural plasticity during acquisition of Brain-Machine-Interface Skill

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Abstract

Interaction with a Brain-Machine Interface (BMI) results in different neuronal tunings as compared to naturalistic movements. We hypothesize that we are able to improve our prediction of these changes based on the neuronal changes during the process of BMI learning. We analysed the monkeys' neural tuning up to 20Hz and under ketamine-induced sedation as they learned BMIs with arbitrary mappings between neural firing rates and cursor position over several weeks. As performance improves, we used Principle Component Analysis (PCA) of brain electrical activity as an estimate of possible constraints on neural plasticity. We also applied a novel algorithm[1] which extracts the dynamical structure of activity modulation to further predict constraints. Due to the short span of time and problems writing the custom MatLab code, we were unable to complete the analyses and have no significant findings.

Introduction

Brain-Machine-Interfaces (BMIs) help patients without control of their limbs improve their quality of life by giving them volitional control over a robotic prosthetic. A key question is how neural activity should best be converted to control signals that can be incorporated as seamless extensions of the patient's motor system. It is observed that neuronal tunings upon interacting with a BMI differ from the tunings derived from naturalistic movements[2].

Our recent experiments have shown that changes in neural tuning are weakly related to the true mapping of individual neurons to the cursor, but are instead 'linked' to produce movements, allowing us to improve our prediction of observed neural tuning changes. We have determined this from principal component analysis of a high dimensional neural space[3].

Aims

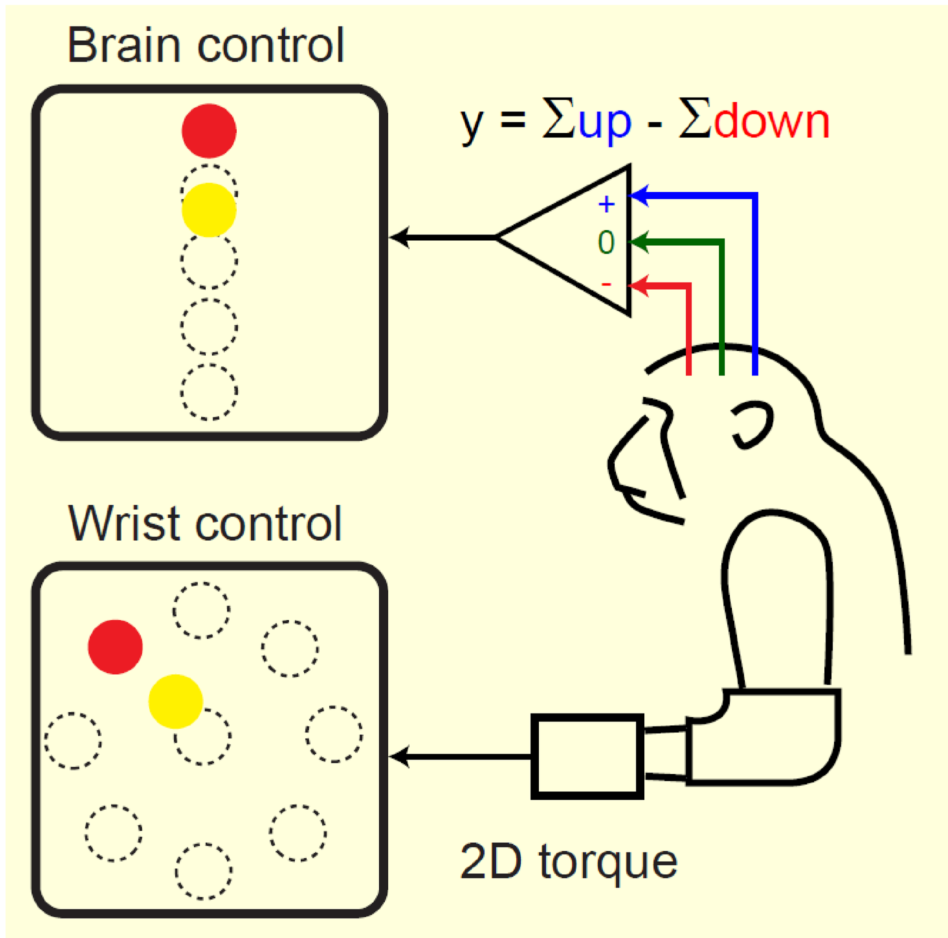
To further predict constraints on neural plasticity, we will:

1. Examine the Correlation structure during natural movements in different frequency bands, including sensorimotor rhythms at 10-20 Hz up to millisecond spike synchrony.

2. Examine whether a novel algorithm [1] which extracts the dynamical structure of activity modulations can further predict constraints on neural plasticity.

3. Examine whether similar correlation structure as observed during awake behaviour is present under ketamine-induced sedation, which includes periods of intense 'up-state' activity.

Methods



We recorded the spiking activity from neurons in the primary motor cortex (M1) and ventral premotor cortices (pMV) of two rhesus macaques, monkey D and monkey R, performing 2D wrist- and 1D brain-controlled cursor tasks over multiple sessions. During brain control, neurons were assigned to up, down and off ensembles according to an arbitrary mapping (Map 1 or Map 2). Instantaneous cursor position was determined from neuronal firing rates.

Data derived from the spiking activity was then analysed using custom Matlab code. We attempted to find the changes in tuning over the different sessions, which is represented in Figures 1 to 3.

Conclusion

The project could not be finished within the stipulated duration. The data, while inconclusive at this point of time, show promising statistical findings.

Results

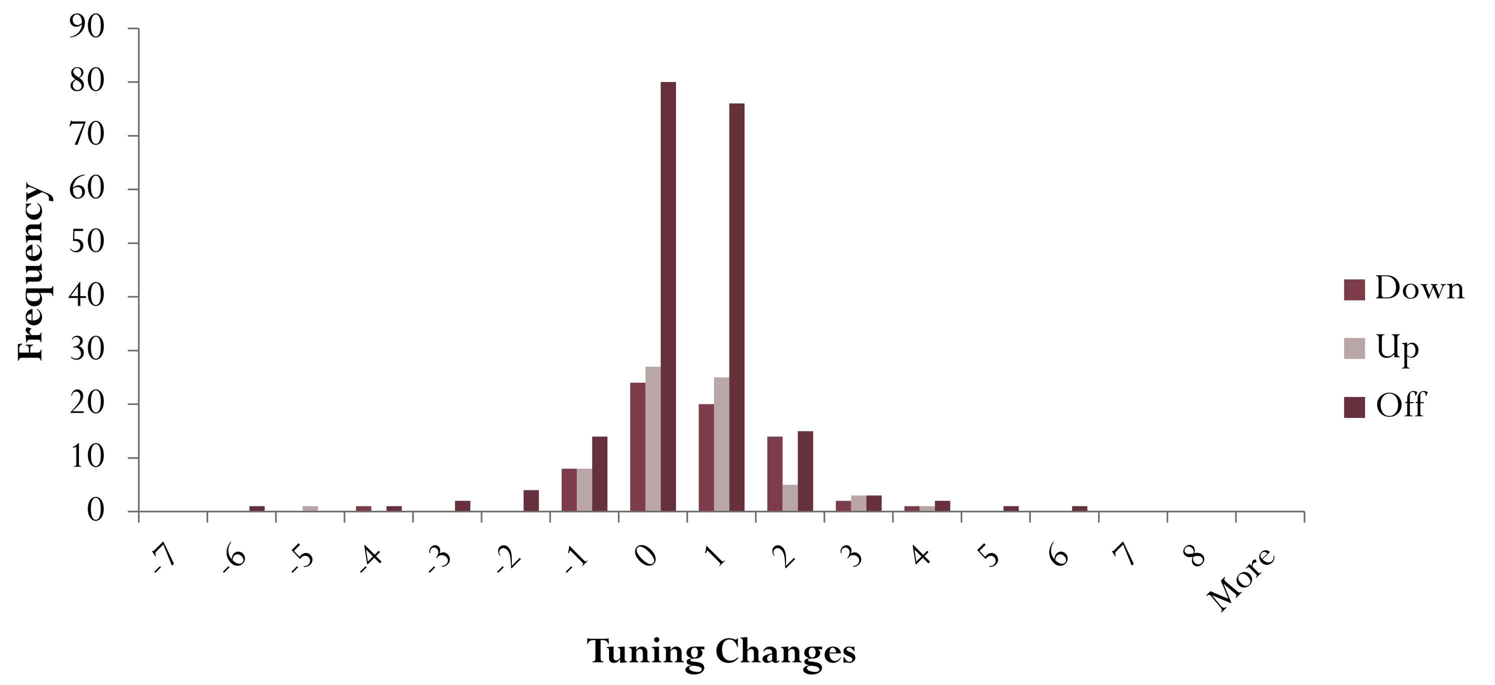


Figure 1. Data Histogram for experiment 1 reveals no predictive tuning changes of 34 neurons over the course of 11 sessions.

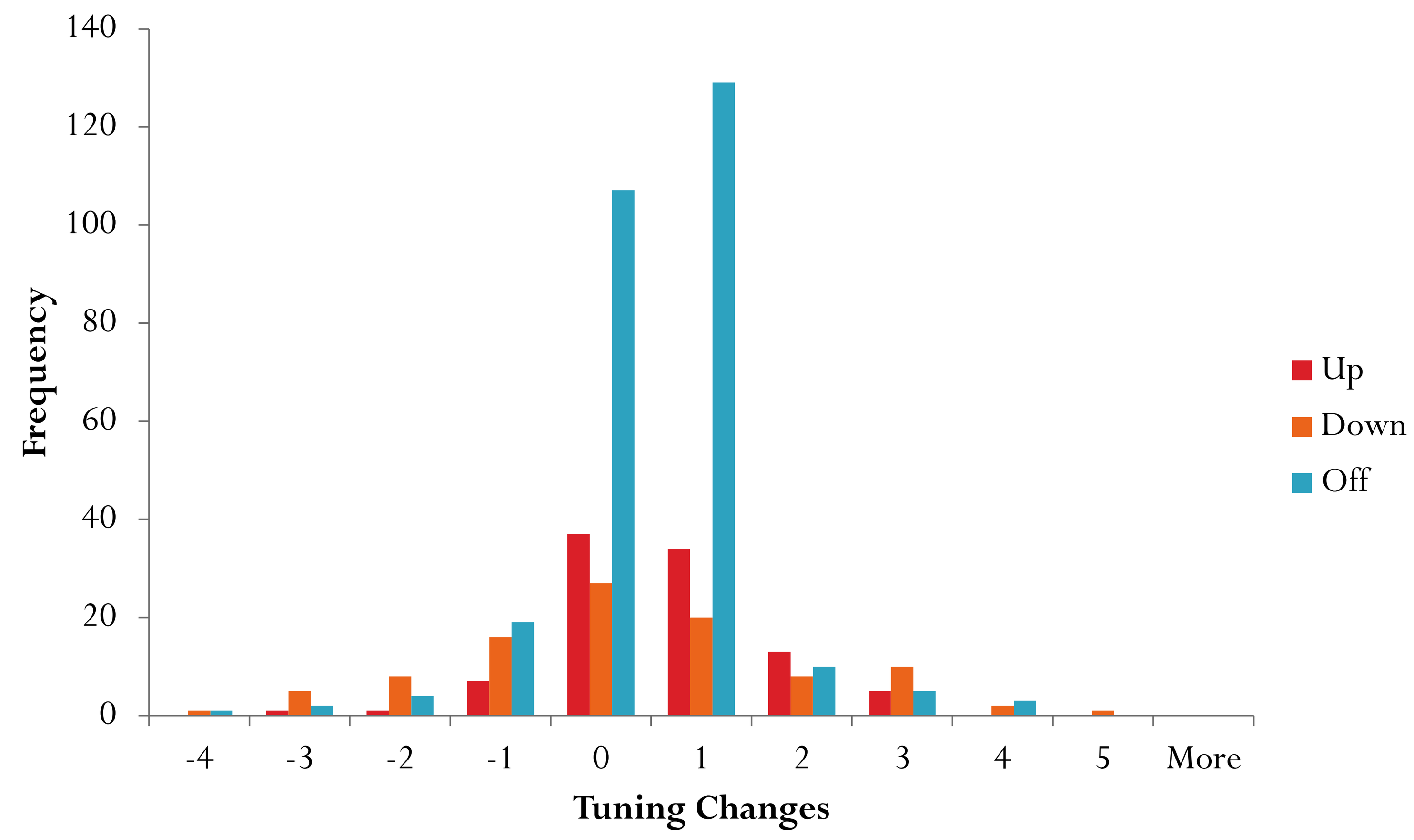


Figure 2. Data Histogram for experiment 2 reveals no predictive tuning changes of 34 neurons over the course of 11 sessions.

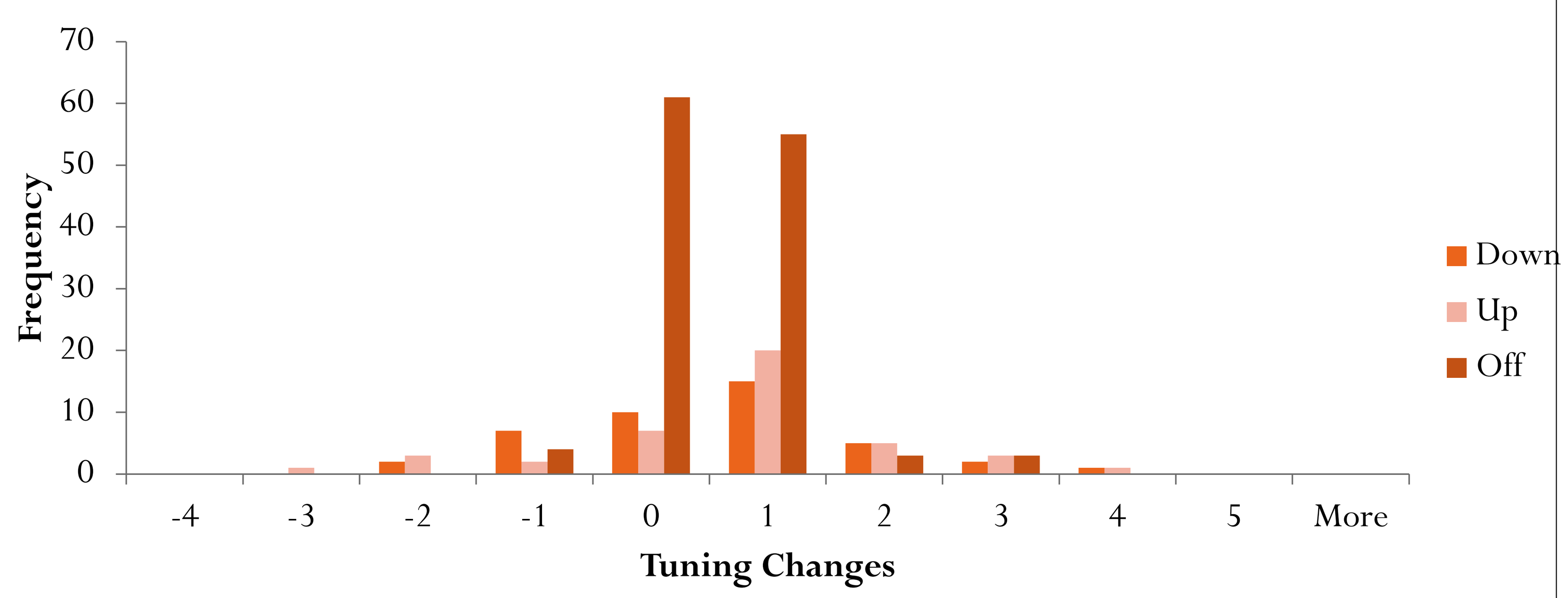


Figure 3. Data Histogram for experiment 3 also reveals no predictive tuning changes of 34 neurons over the course of 14 sessions

References

1. Churchland, M.M., et al., *Neural population dynamics during reaching.* Nature, 2012. **487**(7405): p. 51-6.
2. Jackson A, Fetz EE. *Interfacing with the computational brain.* IEEE Trans Neural Syst Rehabil Eng, 19(5):534-541, 2011
3. Jackson, A., et al., *Predicting changes in neural tuning during BCI learning*