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Decoding decision outcomes from single realizations of lateral prefrontal cortex ensemble activity

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Introduction: Neurons in the lateral prefrontal cortex (LPFC) encode sensory and cognitive signals, as well as commands for goal directed actions. This brain region might be a good signal source for a goal-selection brain-computer interface (BCI) that decodes the intended goal of a motor action previous to its execution. In our previous work we demonstrated that we could decode saccade targets from single-realizations of pre-saccadic LPFC neuronal activity [1]. In this work we examine the neuronal representation of the task and task acquisition, and we decode decision outcomes independent of stimulus information.

Material, Methods and Results: We recorded neuronal spiking activity from microelectrode arrays implanted in area 8A of the LPFC of two adult macaques while they made visually guided saccades to one of a pair of presented targets. The rewarded target was indicated by a colour cue and we changed periodically the association between colour and rewarded direction. In total, four different target pairs and three different colours were used.
Behavioural performance was poor at the onset of each new cue-target rule. The monkeys' performance improved rapidly as they learned the new rule.
We first estimated the latent structure of the ensemble at various stages of the experiment. Latent structure was mostly stable but varied slightly during learning of a new rule despite the structure estimation being blind to the behaviour. We then estimated the internal model that mapped neuronal responses during the pre-saccade period to the rewarded location. The ability of the internal model to predict the rewarded target improved as the monkey learned the task, and in some instances the model outperformed the monkey himself.
We also decoded the intended saccade goal among all eight targets independent of whether or not the saccade was to the rewarded target. The classifier predicted intended saccade goals with good accuracy when the peri-saccade neuronal activity was included in the feature set (82.2 ± 7.6%, chance: 35.7 ± 2.1%). Accuracy was only moderately better than chance when using the average firing rate from the pre-saccade period (45.1 ± 3.6%) but improved when multiple time-points from the pre-saccade period were included (58.4 ± 4.7%).

Discussion: The results from the estimation of the latent structure and the internal model suggest that the ensemble participates in the decision-making process and is plastic in response to the changing task but the plasticity is constrained. BCIs that exploit this latent structure may be able to generalize well across tasks and sessions.
It is unknown if the classification accuracy using peri-saccade data is representative of real-world BCI performance because data from this period might not be relevant in individuals without reliable eye movements and concomitant sensory feedback. For this reason, we focus on using the pre-saccade activity. Using only the pre-saccade activity, classification accuracy was greatest when using features from multiple time-points, revealing the importance of incorporating the temporal dynamics into the analysis. However, the temporal dynamics of the neural correlates of decision-making are inconsistent if the decision-making process is delayed or if the decision outcome is reversed. It will be necessary to use more sophisticated feature extraction and classification techniques to incorporate these temporal dynamics.

Significance: These results provide further evidence that LPFC neurons encode decision processes and suggest that LPFC activity can be used as a signal source for a goal-selection cognitive BCI.

References:

[1] Boulay CB, Pieper F, Leavitt M, Martinez-Trujillo J, Sachs AJ. Single-trial decoding of intended eye movement goals from lateral prefrontal cortex neural ensembles. J. Neurophysiol. (November 11, 2015). doi: 10.1152/jn.00788.2015.