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Proceeding Paper

A Neural Circuit Model of the Striatum Resolves the Conflict between Context and Dominance Apparent in the Prefrontal Cortex †

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Abstract: Neural selectivity is essential to organize information in the brain. Being able to filter the relevant information and to combine different aspects of a task is key to accomplish goal-directed behaviour.

Keywords: context-dependent decision-making; dominance inhibitory control; corticostriatal processing; neural representation; oscillatory activity

In a recent study [1], the authors recorded prefrontal neurons of macaque monkeys performing an attention task. The monkeys needed to respond to a relevant stimulus dimension (orientation or colour, defined by a previously presented cue) to obtain reward. Results from the study showed that prefrontal cells synchronized their activity at beta frequencies during stimulus presentation. Selectivity in the prefrontal cortex (PFC) to either stimulus dimension (orientation or colour) was apparent because coherence at beta frequencies was modulated by two distinct aspects: context and dominance. Context was correlated physiologically with a boost in coherence in the population encoding the relevant dimension. In addition, neural recordings also showed a dominance of orientation against colour. In orientation trials, context and dominance modulations were aligned for orientation-selective cells, which was behaviourally correlated with shorter response times. In contrast, in colour trials no apparent difference was present between the patterns of activity of colour- and orientation-selective cells in PFC due to the disalignment between context and dominance, despite the fact that monkeys performed the task similarly well. Interestingly, the study also reported the presence of pre-stimulus alpha-oscillatory activity in orientation-selective cells, which appeared at the cue onset informing about colour trials.

Thus, a conflict was apparent in colour trials at the level of PFC between dominance (favouring orientation) and context (favouring colour). The fact that monkeys performed the task equally well seems indicative that colour trials may be resolved elsewhere in the brain. The role of pre-stimulus alpha oscillations in orientation-selective cells of the PFC remains a puzzling observation.

Here, we designed a striatal circuit model, based on [2], to test the hypothesis that the conflict between context and dominance is resolved downstream in the striatum. D1 and D2 striatal cells in our model inherit colour and orientation selectivity from cortical inputs. Further additions to [2] are: Inhibitory inputs between cells sharing the same selectivity, i.e., same population, were assumed to be weaker than across populations. Cortical inputs were increased to compensate for the overall increase in inhibition. Orientation and colour trials were simulated based on [1]. Colour trials included not only beta-band cortical inputs but also the pre-stimulus alpha-band input to orientation-selective cells.

Results from our computational model show that, in colour trials, pre-stimulus alpha inputs from cortex activate synaptic depression in orientation-selective cells. Later, during the stimulus presentation, despite that equally strong beta inputs target both striatal populations, their responses become transiently different: orientation-selective striatal neurons become depressed, but colour-selective neurons do not. This creates a window of opportunity to propagate the activation of the colour response through inhibitory control that resolves the conflict between dominance and context present in the PFC.

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