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Abstract

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

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Neural selectivity is essential to organize information in the brain. Being able to filter the relevant information and to combine several aspects of a task is key to accomplish goal-directed behavior. 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 color, defined by a previously presented cue) to obtain a 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 color) 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 color. In orientation trials, context and dominance modulations were aligned for orientation-selective cells, which were behaviorally correlated with shorter response times. In contrast, in color trials no apparent difference was present between the patterns of activity of color- and orientation-selective cells in PFC due to the misalignment between context and dominance, even though 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 of the color trials.

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

Here, we used the DynaSim framework [2] to design and develop a striatal circuit model, aimed to test the hypothesis that the conflict between context and dominance is resolved downstream in the striatum. The model was built upon a previous striatal model [3]. In our model, D1 and D2 striatal cells inherit color and orientation selectivity from cortical inputs. Our further additions with respect to [3] included the assumption that the inhibitory inputs between cells sharing the same selectivity, i.e., the same population were weaker than across populations. Additionally, cortical inputs were adjusted to compensate for the overall increase in inhibition. Orientation and color trials were also simulated based

on [1]. Color trials included not only beta-band cortical inputs but also the pre-stimulus alpha-band input, specifically to orientation-selective cells.

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

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