An integrative model explaining many functions of corticothalamic feedback

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In the early visual system of the cat, the feedforward pathway going from the lateral geniculate nucleus (LGN) to the primary visual cortex (V1) is well characterized both anatomically and functionally. On the other hand, despite a large amount of experimental work, there is poor agreement about functional roles of the feedback pathway from V1 to LGN. The common experimental approach compares system responses taken in the *open-loop* condition - probing thalamus in isolation from cortex - and in the *closed-loop* condition - probing the intact system. In the literature to date this approach has yielded inconsistent results. Open- and closed-loop results for some stimuli differ only by an additive factor, while for other stimuli there is a marked qualitative difference in the results.

In this computational study we investigated the thalamocortical loop with reference to an unprecedentedly broad set of experimental studies. We took published data for six types of experiments (with stimuli varying in luminance, contrast, spatial frequency, temporal frequency, size, and orientation) involving both open- and closed-loop conditions. We explored each condition with an integrative large-scale spiking model of the cat early visual system that includes LGN, peri-geniculate nucleus (PGN), and V1. The model is heavily constrained by the available literature at multiple levels: anatomical, functional, and statistical. The model is developed using the Mozaik workflow engine [1] with NEST [2] as backend simulator.

The experimental constraints enabled us to find a single parameter set that qualitatively and quantitatively accounts for the published responses to all stimuli in both open- and closed-loop conditions. We report that in our model the feedback has additive effects on: spontaneous activity, in agreement with [3], contrast tuning response [4], and temporal frequency tuning [5]. On the other hand, in our model the feedback changes the shape of responses for: spatial frequency tuning, as in [6], size tuning response [7], and orientation tuning [8].

Overall, the thalamocortical loop sharpens responses to visual stimuli by topologically projecting cortical responses onto thalamus [9], such that the reciprocal spatial distribution of cortical and thalamic receptive fields [10] enhances thalamic activities conforming to the highest cortical response and further suppresses unconforming responses.

References

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