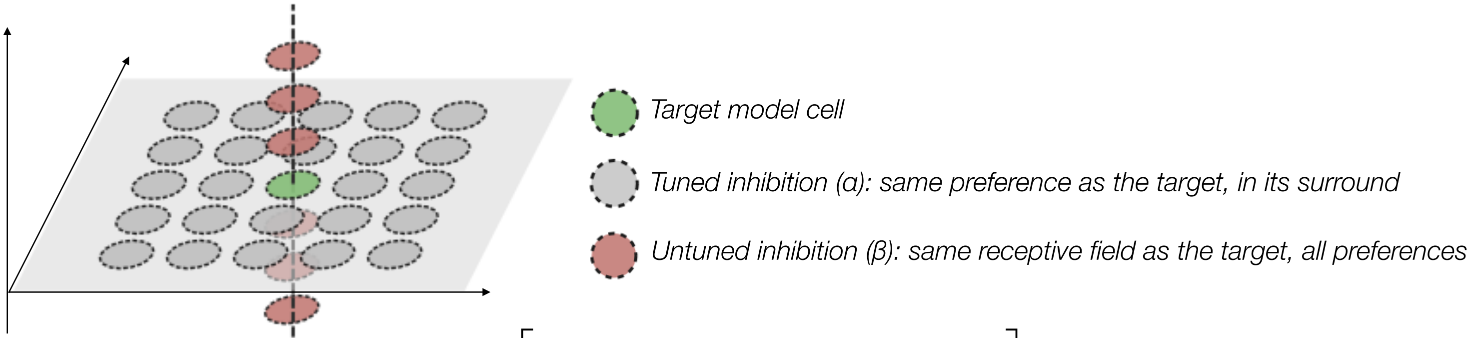
Towards a unified computational model of contextual interactions across visual modalities, Mély and Serre



Temporal dynamics

$$\tau \dot{X}^{\theta}_{i,j} + \sigma^2 X^{\theta}_{i,j} = \left[A^{\theta}_{i,j} - X^{\theta}_{i,j}\left(\alpha \sum_{p,q \in S(i,j)} X^{\theta}_{p,q} + \beta \sum_{\phi} X^{\phi}_{i,j}\right) \right]_+$$

Steady-state (divisive normalization)

$$X^{\theta}_{i,j} = \frac{A^{\theta}_{i,j}}{\sigma^2 + \alpha \sum_{p,q \in S(i,j)} X^{\theta}_{p,q} + \beta \sum_{\phi} X^{\phi}_{i,j}}$$

Target Tuned Untuned

α, β, σ and τ are free parameters adjusted for convergence; X is the activity of the target cell at some location (i, j) in the retinotopic surface and tuned to the value θ; S is the surround pool around cell location (i, j); A is the afferent excitation the target cell gets, and also corresponds to its initial activity before it gets inhibited

Fig. 1. In the proposed circuit, each target cell (in green) receives two distinct forms of lateral inhibition, untuned and tuned. With untuned inhibition (in red), the suppressive signal is pooled over all cells sharing the same receptive field, but with varying tuning preferences (along an arbitrary tuning axis *θ*). Untuned inhibition has been widely used as a form of local gain control. With tuned inhibition (in gray), the suppressive signal is pooled in the surround of the target cell, outside its receptive field, over only those cells with similar preferences as the target cell. At the population level, the response is thus suppressed unevenly, which enables complex transformations of the population response curve such as shifts. In our simulations, we iterated a dynamical system incorporating the two forms of inhibitions, until it converged to a steady-state where each cell's activity corresponds to a divisive normalization equation.

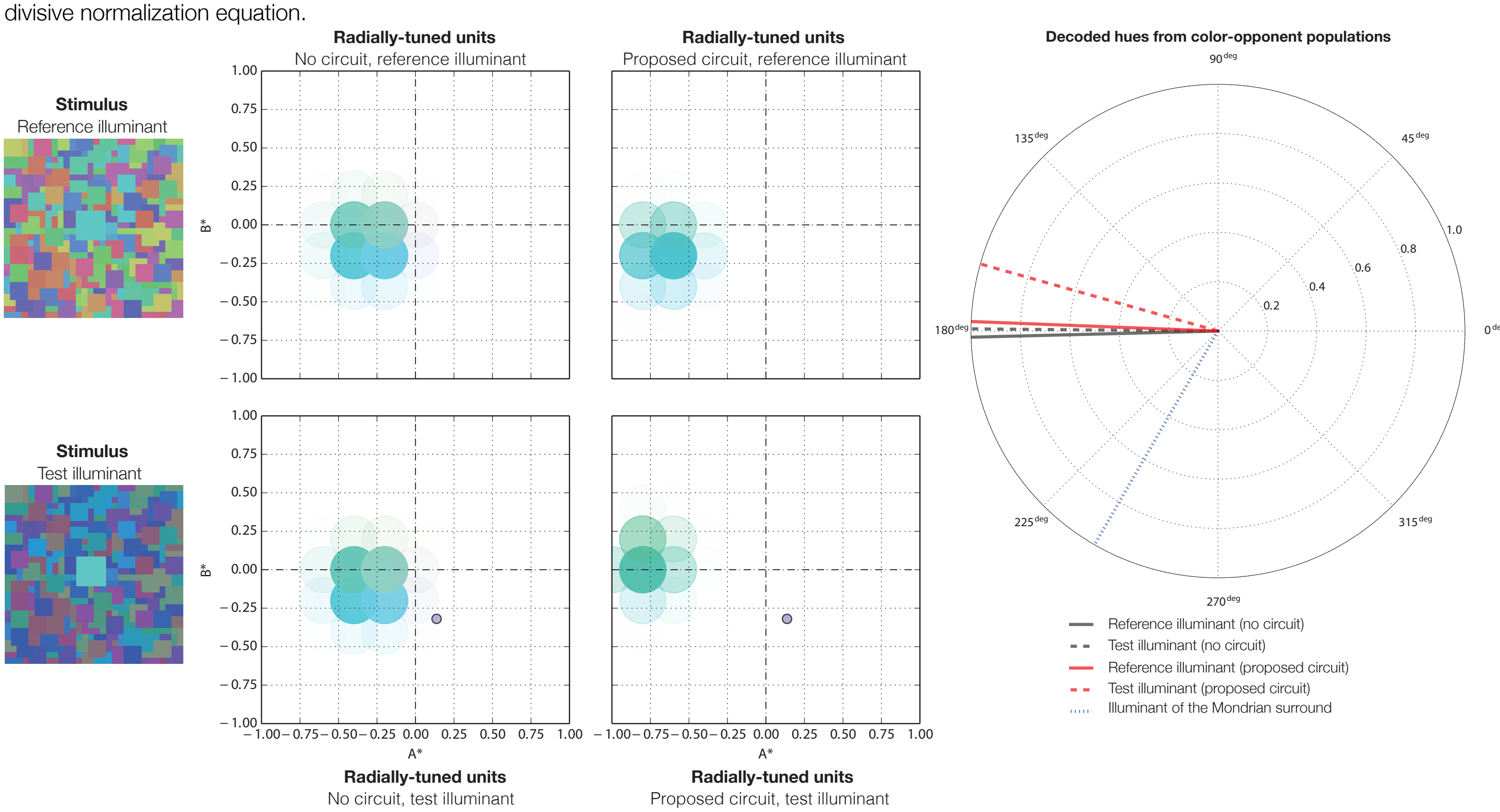


Fig. 2. The proposed circuit explains color induction through shifts in perceived hue decoded both from color-opponent populations of model cells, as well as from higher-level radially-tuned color-tuned populations of model cells. We used a simple model of cortical processing of color, beginning with an V1-like stage where model units are monotonically tuned along color-opponent axes (A* and B*, standing respectively for Red-Green and Blue-Yellow), then applied lateral inhibition as explained in **Fig. 1.** (our proposed circuit), followed at last by a V4-like stage of model units tuned to position in the A*-B* plane. Following Kusunoki et al. (2006), we embedded color patches in Mondrian backgrounds, and decoded measures of their perceived reflectance for two background illuminants while keeping the central patches' illuminant unchanged (stimuli illustrated on the far left). The classical receptive fields (cRF) of the cells we decoded from were always within the extent of the central patch; as such, the input to the cRF of the cells we decoded from remained constant across conditions. We first decoded the hue angle from a V1-like population (right, radar plot); the model cells could either be incorporated in the proposed circuit (red lines) or not (null model, black lines). Switching from a reference illuminant (plain lines in the radar plot; upper stimulus) to a test illuminant (dashed lines; lower stimulus) induced a significant repulsive shift of central patch hue relatively to the color of the test illuminant itself (fine dashed blue line in the radar plot), *only with the proposed model*, consistently with Kusunoki et al. A similar effect was found when considering the higher-level V4-like population response (center plots; transparency indicates activity, blue point represents the illuminant) tuned to position in the A*-B* plane: the center of gravity of the population was shifted away from the illuminant color.