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Feedforward Models of Contrast-Invariant Orientation Tuning

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Introduction Cortical simple cells respond best to dark-light transitions of a specific orientation, i.e., their response is orientation tuned. Further, the width of the tuning curves does does not depend on the contrast of the dark-light transition. This property of contrast invariant orientation tuning (CIOT) cannot be reproduced by a simple feedforward model (Ferster & Miller, 2000), which leads to the advocation of recurrent processing to generate CIOT (Somers, Nelson, & Sur, 1995; Ben-Yishai, Bar-Or, & Sompolinsky, 1995). We present a feedforward model which is capable to generate CIOT by using inhibition between complementary pathways.

Methods The model consists of an initial stage where the input is processed by center-surround filters similar to retinal ganglion cells to generate on- and off-contrast responses. These contrast responses are sampled by elongated, offset subfield masks for both contrast polarities. Responses of on- and off-subfields are added to generate simple cell response. Inhibition can be introduced at two positions within this hierarchical processing: *at the subfield level*, where a subfield is inhibited by opposite contrast responses (Ferster, 1989), or *at the simple cell level*, where a simple cell is inhibited by a simple cell response of opposite contrast polarity. We study the effect of inhibition on orientation tuning curves and varied the strength of inhibition.

Results Simulation results validate that a plain feedforward model without any inhibition cannot produce CIOT. By introducing either kind of inhibition, however, the model simple cells exhibit CIOT. Increasing the strength of inhibition sharpens the orientation tuning curves. Weights of 1–2 for the inhibitory contribution result in physiological plausible tuning widths.

Conclusion We developed a functional model of simple cells using only feedforward processing. Results show that inhibition is sufficient to produce CIOT under a feedforward regime. We conclude that inhibition is the primary source of CIOT. Recurrent interactions might be used to further sharpen or modulate these tuning curves based on contextual information.

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