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COMPUTATIONAL MODEL OF THE EFFECTS OF SHORT-RANGE EXCITATION AND INHIBITION ON ORIENTATION SELECTIVITY IN VISUAL CORTEX.

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Our lab recently reported that intracellular blockade of inhibition in single cortical cells does not disrupt orientation selectivity (Toth et al. '92). This is consistent with reports that EPSPs are well-tuned for stimulus orientation (Ferster '86); however, it conflicts with reports that inhibitory blockade over a small region of cortex disrupts orientation selectivity (Sillito '75). We have constructed a model of a patch of layer IV of area 17 in order to reconcile these and other orientation selectivity data. Model cortical neurons received synaptic input from LGN neurons and nearby cortical excitatory and inhibitory neurons. The total pattern of LGN inputs to all cells in an orientation column came from a 3:1 oriented patch of visual space (Chapman et al. '91). However, the pattern of LGN inputs onto single cortical cells varied and was often only weakly oriented. Short-range cortical excitation and inhibition generated sharp orientation selectivity for all cortical cells. EPSPs and IPSPs recorded in single cells had the same preferred orientation with the IPSPs more broadly tuned. This inhibition in the absence of cortical excitation sharpened tuning, but also greatly attenuated response strength.

Simulated iontophoresis of the GABA antagonist bicuculline methiodode, implemented as an 80% blockade of inhibition on all cells in an orientation column, disrupted selectivity. Reduction of inhibition permitted recurrent cortical excitation to generate strong (but not saturating) responses to all orientations. Blockade of inhibition in single cells, however, produced only mild broadening of a cell's selectivity. EPSP tuning was unaffected and produced well-oriented responses. Injection of hyperpolarizing current into a blocked cell, reducing the maximal response to pre-blockade levels, yielded selectivity matching that observed prior to blockade. These simulations suggest that all 3 types of synaptic input contribute to orientation selectivity: LGN inputs provide a distributed orientation bias to a column; cortical inhibition sharpens selectivity and reigns in excitation; short-range cortical excitation amplifies responses and integrates the pattern of LGN input to a column. Such columnar integration reduces the degree of specificity in afferent connections required to generate highly selective responses.

KEY WORDS: (see instructions p. 4)

1. bicuculline
2. cortical circuits
3. positive feedback
4. cortical column

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