Bandwidths of Cigars and Doughnuts in higher-level spatial vision
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Introduction

Olzak and Thomas (1999) described two spatial vision pathways in early-to-middle cortical vision based on two Fourier dimensions, orientation and spatial frequency. Each sums over pools of early tuned mechanisms, first to form a gain control pool and then a different pool in which responses are summed together. One pathway provides information about the orientation of edges and lines, and is broadband with respect to spatial frequency but narrowly tuned for orientation (cigars). The other provides information about the textural grain, or 2-D spatial frequency content of textures, and is broadband with respect to orientation but narrowly tuned for spatial frequency (doughnuts). The current study is focused on measuring the bandwidths of two of the processes believed to be involved in both pathways: normalizing pools (gain control pools) and summing circuits.

Methods

Observers
- One graduate; 10 undergraduates, all normal or corrected to normal. Not all observers participated in all conditions.

Task
- Discriminate between two sinusoidal patterns on the basis of either slight differences in orientation or spatial frequency.

Conditions
- Control (simple 3 cpd vertical sinusoid)
- Masking to isolate gain control pool
- Two cues—vary together
- Two cues—vary in opposition

Procedures
- Blocks of 80 trials, interleaving the two stimuli to be discriminated.
- Five repetitions at each orientation difference.
- On any trial, one stimulus appeared for 500 ms, followed by a 5000 ms response period.
- Signal detection rating scale (1-6) certainty as to whether stimulus A or B had been presented.
- Calculate daily d’, average over 5 replications of each condition.

Experiments
- Isolate Cigars with orientation judgments. Mask and second cue initially vertical at 15 cpd.
- Change orientation of second component in different sessions to measure orientation bandwidth of cigar pathway.
- Isolate Doughnuts with spatial frequency judgments. Mask and second component initially orthogonal (horizontal) at 3 cpd.
- Change spatial frequency of second component to measure spatial frequency bandwidth of doughnut pathway.

Results

Doughnuts
- The gain control pool associated with doughnut mechanisms is very broad with respect to spatial frequency.
- Fitted Gaussians on data averaged over all observers yielded a half height full bandwidth of 2.0 cycles.

Cigars
- The gain control pool associated with cigar mechanisms is very broad with respect to orientation. Fitted Gaussians on data averaged over all observers yielded a full bandwidth, half height of 116°. Summing circuits, however, were very narrow, with a half height, full bandwidth of 2°.

Discussion

Assuming that there is a single gain control pool underlying both orientation and spatial frequency judgments, then the pool associated with fine spatial discriminations is broadband with respect to both dimensions. This is consistent with previous estimates and models based on detection tasks (Foley, 1994; Watson & Solomon, 1997). The summing circuit results involved in these spatial discriminations, however, were surprising. The ranges over which the circuits operate is exceedingly narrow, especially relative to first-stage filters. While broadband mechanisms are capable of making finer discriminations (e.g., color), a mechanism desiged to average spatial frequency in a texture or orientation information in an edge would be best served by increasing the likelihood that the information came from the same surface or edge. One way of doing this is to narrow bandwidth with respect to the dimension the mechanism is summing over.

References


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