Editorial: long range interactions in vision

Perhaps the most fundamental discovery in vision during the twentieth Century, was the discovery of neuronal receptive fields — i.e. that neurons in the visual nervous system respond to stimuli on a specific, very limited region of the retina. Stephen Kuffler was the first to describe the receptive field organization of the mammalian retina (Kuffler, 1952), and the work of Kuffler’s young proteges, David Hubel and Torsten Wiesel (1959), describing the receptive field properties of cortical neurons, led to the Nobel prize, and to much of our current thinking about visual processing.

The classical receptive field acts as a filter, ensuring extraction of local information uncontaminated by irrelevant nearby stimuli. However, there is a fundamental tension between the need for purely local processing in vision, and the need to integrate information across space in order to identify useful parts of the field of view (such as objects, extended regions of similar texture, color, motion or depth). Thus, there is a clear need for long range processing in vision, and in recent years it has become clear that both early and late stages of visual processing incorporate long range processes which contribute to a wide variety of remote effects, context effects, grouping processes, texture segmentation and more.

There is ample anatomical and physiological evidence for long range lateral connections which form a dense network within many regions of the primate visual cortex (Rockland and Lund, 1983; Blasdel et al., 1985; Fitzpatrick et al., 1985; Yoshioka et al., 1992; Levitt et al., 1993; Lund et al., 1993; Amir et al., 1993; Levitt et al., 1994). In primate cortex these intrinsic connections spread up to a distance of about 2 mm in V1. Recent estimates of human cortical magnification, based on functional imaging (Horton and Hoyt, 1991; Engel et al., 1994; Sereno et al., 1995) suggest that in V1, the cortical magnification factor in the fovea may be in the order of 25 mm/deg (see Beard et al., 1997, for a quantitative re-analysis of the human cortical magnification factor based on functional magnetic resonance imaging data). Thus, the approximately 2 mm spread of long-range connections in V1 represents a spatial distance of only about 5' in the fovea, and a distance of about 0.1 times the eccentricity at large eccentricities. The extent of long-range lateral connections increases at increasingly higher levels in the cortical hierarchy (up to about 4 mm in V2, 5–6 mm in V4 and 9 mm in area 7a, see Amir et al., 1993). These distances, according to Amir et al., are equivalent to or even larger than the cortical ‘point image’ (i.e. the product of receptive field size and cortical magnification).
Moreover, long-range connections can be extended by forming chains of laterally connected neurons. Thus, lateral connections may be important both in shaping the classical receptive fields (e.g. Boltz and Gilbert, 1986), and in producing effects beyond the borders of the ‘classical’ receptive field (Gilbert et al., 1990; Gilbert, 1992; Amir et al., 1993).

The long-range connections in the primate visual cortex may be both excitatory and inhibitory. It has been estimated that perhaps 70–80% of long-range connections have excitatory synapses, and the balance synapse on inhibitory interneurons, and the connections appear to be primarily between areas with similar receptive field characteristics (e.g. orientation, spatial frequency or color) and are elongated along the orientation axis of the neuron (for a collection of recent reviews see Sirosh et al., 1986). The pattern of connections can be altered by abnormal visual experience (e.g. strabismus, see Lowel and Singer, 1992).

The publication of this (double) special issue of Spatial Vision was triggered by the 1998 Forum of European Neuroscience workshop on ‘Long Range Spatial Coding by the Visual Cortex’ organized by Birgitta Dresp. The issues devoted to these long-range interactions cover a broad range of topics, both theoretical and experimental, which involve long-range processes in vision. The papers in these issues are freely submitted manuscripts that could be processed prior to press time, and represent a broad cross-section of contemporary research on the topic of long-range interactions. Some of the findings and models presented here are likely to be provocative, and will surely require elaboration as we learn more about the underlying physiological processes; however, what emerges clearly, is that to truly understand vision, we will have to understand the rich network of long-range connections that enable us to bind together the features that form an object, and segregate them from their background.

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REFERENCES

