Does primary visual cortex perform a wavelet-representation of spatial frequencies?

Tobias Teichert,Thomas Wachtler, Alexander Gail,
Hans-Jörg Brinksmeyer, Frank Michler, Reinhard Eckhorn

Philipps University, Department of Physics, NeuroPhysics Group, 35037 Marburg,Germany

Introduction. Our visual system is selective for spatial frequencies, which are a measure of spatial resolution. Psychophysical evidence, primarily based on adaptation to grating stimuli, suggests the existence of spatial frequency channels. Models of visual perception often use a set of localized spatial frequency filters, typically based on oriented Gabor-wavelets that are scaled in spatial size inversely proportional to their optimal spatial frequency. This results in identical relative spatial frequency tuning widths. At any given eccentricity neurons in primary visual cortex show tuning with best frequencies and bandwidths over a range of 3 to 4 octaves [1]. If these *neural spatial frequency filters* represent a Gabor- or other wavelet basis, the sizes of their receptive fields are expected to increase inversely proportional to their optimal spatial frequency. We examined, whether evidence for such a relationship can be found in multi-unit activity of upper layers of primary visual cortex that are the origin of efferences to higher visual cortical areas.

Methods. We recorded multi-unit activity in the upper layers of awake macaque primary visual cortex. Preferred spatial frequency and spatial summation field size (size of patch with optimal orientation and spatial frequency that evokes strongest response) were determined by observing responses to Gabor patches of six different sizes ($0.1 - 5.0$ deg) and seven spatial frequencies (0.7-8.0 cycles/deg) centered on the classical receptive field. Preferred spatial frequency and spatial summation field size were estimated using a bootstrap method and interpolating the response strength on the 6x7 patch size/spatial frequency grid.

Results. We found a significant negative correlation between preferred spatial frequency and spatial summation field size. Contrary to predictions from a wavelet coding concept, there was a significant increase of relative size of the spatial summation field (i.e. wavelength of preferred spatial frequency/spatial summation field size) with increasing preferred spatial frequency. Spatial frequency bandwidth decreases as relative size of the spatial summation field increases. We could also show, that spatial frequency bandwidth depends on patch size, increasing at sizes below the size of the spatial summation field.

Conclusions. Multi-unit activity recorded from complex-cells in upper layers of primary visual cortex shows similarities to localized linear frequency analysis. However, the relationship between size of the spatial summation field and preferred spatial frequency corresponds neither to wavelet nor windowed Fourier analysis.

Literatur

[1] R.L. De Valois, D.G. Albrecht, and L.G. Thorell. Spatial frequency selectivity of cells in macaque visual cortex. *Vision Research*, 1981.