

Spatial Symmetry and Stability of V1 Receptive Fields Analyzed by Two-Dimensional Hermite Functions

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The concept of a receptive field is central to understanding sensory systems. It succinctly describes neural feature selectivity and quantitatively predicts responses to synthetic and natural stimuli. Simple receptive field models are typically inadequate: though they may account for responses to one class of stimuli, their components appear to be modulated by input statistics (i.e., context). Characterizing these modulatory effects remains a challenge. We address this problem in primary visual cortex of cat and macaque, where such modulatory effects are considered to have substantial functional significance. We do this by analyzing responses of neurons to two stimulus sets: two-dimensional Hermite functions (TDH's) that are matched in spatial extent, contrast, and power, but differ in their two-dimensional organization [1]. We find that coarse spatial features of receptive fields are less modulated by context than fine details. More surprisingly, independent of spatial scale, receptive field components that are invariant under 180-degree spatial rotation are less susceptible to modulation by context than components that do not have this invariance (Figure). This was observed in receptive fields computed via reverse-correlation [1] or maximally-informative-dimension [2] methods. Our results may have implications for not only adaptive properties of neural circuits, but also learning rules that guide their development.

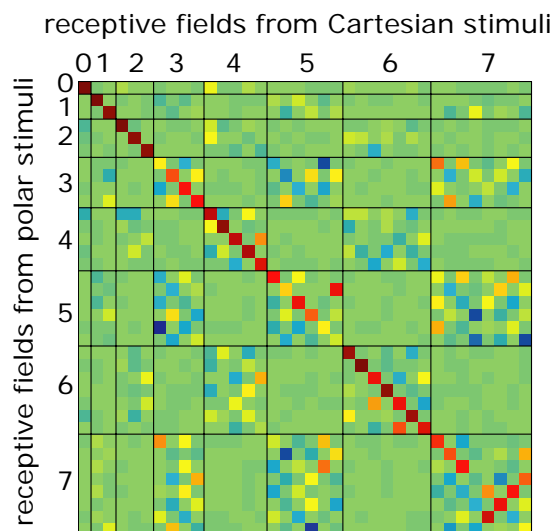


Figure. Relationship – best rotation matrix – between a set of computed receptive fields (n=51) for Cartesian and polar stimuli. Receptive fields under both conditions are specified by their 36 projections onto polar two-dimensional Hermite functions. Stimulus dimensions are grouped by their rank, from 0 to 7, with patterns of lower rank describing more coarse and central features, and high rank patterns more extended in space with finer spatial organization. All patterns of even rank are invariant under 180-degree spatial rotation, and all patterns of odd rank change into their negative with 180-rotation. Changes in apparent receptive field shape are manifest by departures of the illustrated matrix from the identity. These departures are more prominent for odd-rank components than even-rank components.

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References

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