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Title: Extra-classical receptive field properties from natural image statistics

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Authors: ***U. A. ERNST**, S. DENEVE;
Ecole Normale Superieure, Group for Neural Theory, Paris, France

Experimental studies have demonstrated that stimuli outside the classical receptive field (cRF) of a neuron, which would elicit no response when presented alone, can nevertheless strongly modulate the cell's response to stimuli inside the cRF. These non-linear, non-classical receptive field (ncRF) properties can drastically change the neuron's behaviour, as e.g. its preferred orientation. They can also act differentially depending on stimulus contrast, enhancing the firing rate when the contrast inside the cRF is low, and suppressing the activity when the contrast is high. Several mechanistic models have been proposed to account for the observed phenomena, but few studies have investigated the computational role of ncRFs. Here we explore the hypothesis that ncRF properties emerge from natural image statistics, as a byproduct of a learning process which seeks to find statistical interdependencies between noisy observations from spatially separated channels (i.e., pixels or oriented edges in an ensemble of images).

More specifically, we learn a generative model with predictive weights, which expects that each observation is generated by one or more independent causes with its corresponding probabilities. This assumption is justified by one of the fundamental properties of a natural scene: when two objects overlap, one observation is either caused by one, or by the other object. After learning, we subject our model neurons to stimulation protocols typically used to probe for ncRF properties. We find that many neurons develop extraclassical response patterns similar to those which were found empirically. The distribution of these neurons, and the emerging ncRF phenomena depend on the details of the stimulation protocol, giving a putative reason for the variety of observations reported in the literature. We also find strong differential modulations in dependence on stimulus contrast, which can be mathematically analyzed and understood as a consequence of 'explaining away' observations that were already accounted for. Taken together, these results suggest that ncRF modulations might be re-interpreted as a consequence of a neural process inferring the independent external causes underlying a noisy sensory input.

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