# ‘Preferred’ stimulus of a whole model visual system

O.Penacchio and J.M.Harris
School of Psychology and Neuroscience, University of St Andrews, Scotland, UK

In its broader definition the receptive field of a neuron refers to spatiotemporal characteristics of the stimulus that elicits the most intense response activity. In this work, we define and use a theoretical framework to investigate the characteristics of the stimuli that produce the strongest response activity in a model generic visual system. Simply put, given a model visual system, we want to determine its ‘preferred’ stimulus.

Beyond its theoretical interest, our motivation for considering such a problem is twofold. First, there is growing evidence that certain patterns that cause visual discomfort, and may provoke seizure in hypersensitive individuals, trigger an unusually strong cortical activity. Typical examples of such detrimental patterns include black and white stripes, as well as arrangements of dots. Similar patterns, on the other hand, are observed in animal warning signals, a class of distinctive colourations by which some species advertise to predators that they are toxic or more generally unprofitable. Again, since conspicuousness seems to be a central characteristic of warning signals, the patterns involved may be optimized to provoke a distinctive, strong activity in the visual system of the receiver.

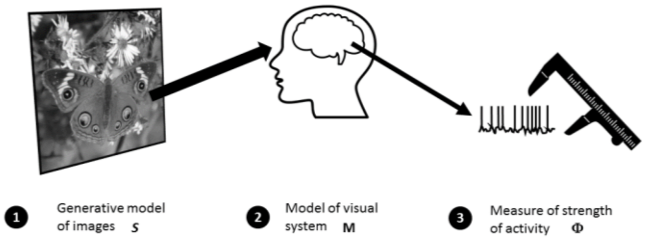


**Figure 1. Schematic of theoretical framework.**

The theoretical framework we considered to derive the notion of ‘preferred’ stimulus of a whole visual system has three buildings components (see Fig.1). The first component is a set of possible stimuli **S**, or ‘images’. The second component is a generic model visual system, **M**. The third component is a measure $\mathbf{\Phi}$ of the strength of activity of the model visual system in response to stimuli in the space of images. Our inference problem therefore reduces to finding the stimuli in the space of images that maximize the measure of the response activity of the model, or

$$\widehat{\mathrm{im}} = \underset{\mathrm{im}\,\epsilon\,\mathbf{S}}{\mathrm{argmax}}\,\mathbf{\Phi}(\,\mathbf{M}(\mathrm{im})\,)$$

Such an inference problem is challenging. The space of stimuli should be complex enough to avoid possible solutions to be restricted to a narrow class of images, but should be computationally tractable. The model visual system should be based on plausible biophysical circuits for biological relevance, but the cascade of operations typically involved is computationally costly and, again, may render the problem intractable. Finally, what the most adequate definition of a strong activity is for the two motivating problems is uncertain. E.g., should this measure relate to the sparseness of the distribution of the response activity or relate to the norm of the response of the units in the model?

To simplify the problem, we ignored the temporal aspect of the stimuli. As the main building block of the model we used V1-like simple cells modelled as Gabor filters sensitive to different orientations and spatial scales, with no lateral connections between units. The strength of activity of the model response was measured as the $L_2$-norm of the whole set of units in the model. To prevent any loss of generality for the space of possible stimuli, the inference was made on the whole set of pixels in the images, with pixel values constrained between 0 and 1.

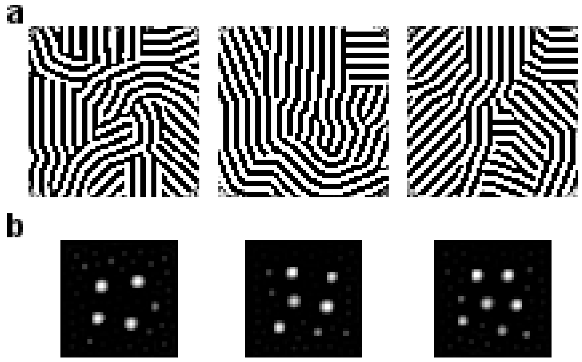


**Figure 2. Examples of stimuli that maximize the strength of activity (here, the L_2 norm of the activity of all the units) of the model when the model is made of a set of V1-like Gabor units sensitive to eight possible different orientations and (a) a single spatial scale or (b) four different scales.**

We showed through simulations that the ‘preferred’ stimuli of such a model visual system are reminiscent of the patterns known to produce visual distress and share many characteristics with the patterns involved in animal warning signals (see Fig. 2). We thus offer computational evidence that visual distress may be induced by an overload of cortical activity and also suggests that the design of animal warning signals could result, at least in part, from evolutionary pressure to generate an excess of neural activity in predators’ visual systems.

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