Can we understand colour processing in the visual system from the statistics of natural scenes?

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The notion that neural processing is adapted to the sensory environment has been a successful basis for explaining coding properties of neurons in the visual system. To investigate whether this approach can provide insights into the principles underlying the properties of colour processing, we analyzed natural scenes with respect to the coding of colour. A fundamental requirement for colour vision is the ability to process visual signals in a cone-type specific way. Analyses of cone response estimates to natural scenes show that cone-type selective wiring can be acquired in an unsupervised manner, based solely on the statistics of the cone responses. This finding supports recent theories of the evolution of trichromatic vision in primates. A prominent feature of colour processing is colour opponency. Opponency has been proposed to be a consequence of the overlapping cone spectral sensitivities. However, an analysis of natural images showed that opponency is an efficient way to represent spectral information in natural scenes, independent of the cone spectral sensitivities. This suggests that colour opponency is a consequence of the properties of the visual environment, not primarily of the photoreceptor spectral sensitivities. As a result of opponent processing, colour selectivities in retina and LGN cluster around the orthogonal axes of cone-opponent colour space. In visual cortex, however, colour selectivities are more distributed and not organized around orthogonal colour space axes. Efficient codes for cone responses in natural scenes show a preference for opponency along non-orthogonal axes in colour space, similar to the colour preferences of neurons in the visual cortex. This suggests that the transformation of colour signals from retina to visual cortex achieves a representation that is adapted to the statistics of colour in natural scenes.