Haemodynamics, hypermetabolism and homeostasis

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The visual system evolved to process images encountered in nature, which are scale invariant. The Fourier amplitude spectrum of such images decreases with the reciprocal of spatial frequency (1/f). Natural images may, in principle, be processed efficiently with a sparse code. In several studies we found that ratings of discomfort from a wide range of images could be predicted by the extent to which the image amplitude spectrum departed from 1/f. The greater the departure, the greater the discomfort, suggesting that the images that are inefficient to process may be uncomfortable to look at.

Gratings provide a simple but unnatural stimulus that departs maximally from 1/f. In a study that compared patients with migraine and headache-free controls, the amplitude of the fMRI BOLD response to gratings was larger for those gratings with mid spatial frequency, which are the most uncomfortable. The BOLD response was abnormally large in the patients with migraine who found the uncomfortable patterns particularly aversive. The abnormal BOLD response was reduced using coloured filters the patients reported as comfortable to wear, but not with control filters.

A further series of studies using near infrared spectroscopy investigated the amplitude of the oxyhaemoglobin response to gratings in which the bars differed in colour but not in luminance. The amplitude was positively correlated with the perceptual difference in the component colours. The larger the perceptual difference the greater the discomfort. Once again, images that were uncomfortable were those that elicited a large haemodynamic response.

In the above studies, a large haemodynamic response was associated with discomfort, both with respect to the differences between images, and with respect to the differences between people. We therefore propose that the discomfort is homeostatic and acts to reduce oxygen hypermetabolism.