
JOSA COMMUNICATIONS

Communications are short papers. Appropriate material for this section includes reports of incidental research results, comments on papers previously published, and short descriptions of theoretical and experimental techniques. Communications are handled much the same as regular papers. Proofs are provided.

Decorrelation of L- and M-cone signals

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For a large sample of broadband lights reflected from natural and man-made objects, the correlation between L- and M-cone absorptions was found to be 0.99. The correlation between L + M and L − M signals was 0.21. The early recombination of cone signals in the visual system thus leads to a substantial decorrelation [Proc. R. Soc. London Ser. B **220**, 89 (1983)]. © 1997 Optical Society of America [S0740-3232(97)01812-7]

Key words: Cone signals, opponent-color signals, decorrelation.

1. CONE AND POSTRECEPTORAL CORRELATIONS FOR BROADBAND LIGHTS

Psychophysical and physiological estimates have shown that there is considerable overlap between human L- and M-cone absorption spectra,[1,2] thus predicting a substantial correlation between L- and M-cone signals from objects in a visual scene. For monochromatic lights the Pearson correlation coefficient between L- and M-cone absorptions is 0.86. Buchsbaum and Gottschalk[3] noted from simple engineering principles that it would be inefficient to transmit two separate highly correlated signals from the retina to the cortex. They showed that when cone signals from monochromatic lights are optimally decorrelated by use of a transform based on the eigenvectors of the variance–covariance matrix, the transformed linear combinations bear a resemblance to the luminance and opponent-color mechanisms of color theory.

The lights normally incident on the retina, such as those reflected from objects, have broadband spectra, and it is possible that the correlation between L- and M-cone absorptions for these lights can be even higher than for monochromatic lights. The main purpose of this Communication is to present the unexpectedly high magnitude of this correlation. The 170 spectra of natural and man-made objects measured by Vrhel *et al.*[4] were taken as the sample of objects. The Smith–Pokorny[1] estimates were used for L- and M-cone absorption spectra, and absorptions for each cone type were calculated for each object illuminated by a unit amount of equal-energy light (the L and M spectra were normalized to equal area). In Fig. 1 (top), each point represents the M-cone absorption from an object plotted versus the L-cone absorption. The correlation between these signals is 0.99 and is shown clearly in the figure. (The average pairwise correlation between the reflectance spectra of the 170 objects is 0.5341.) It is obvious that it would be desirable to decorrelate L- and M-cone signals from objects at a very early stage in the visual stream. In Fig. 1 (bottom) are plotted the L + M signals from these objects versus the L − M signals. The points are now spread over the graph, and the correlation between the signals is only 0.21. The decorrelation is robust within a range of reasonable relative weights of L and M signals in the combinations.

One other point should be noted about Fig. 1 (bottom).

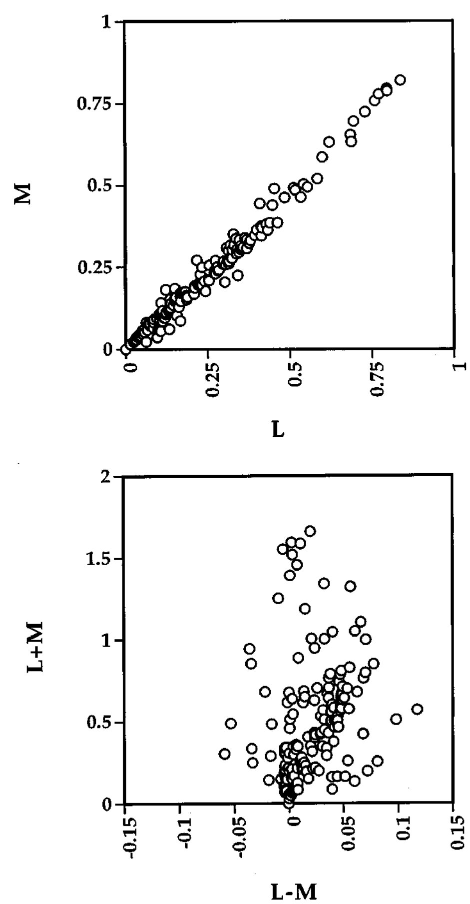

Fig. 1. Top, M-cone absorptions from 170 objects in equal-energy light plotted versus L cone absorptions; bottom, L + M signals from the same objects plotted versus L − M signals.

Because of the high correlation between L and M signals, the range of L − M is an order of magnitude smaller than the range of L + M. For most scenes the spatially antagonistic center-surround structure of the receptive fields of postreceptoral neurons serves to bring the ranges of the two classes of signals closer in magnitude. Whereas local L − M signals are transmitted to the cortex by the parvostream, both the parvostream and the magnostream convey only the L + M spatial-contrast signal, i.e., the difference between the center and the surround L + M signals.[5] Since local spatial variations in L + M signal are generally small, the range of the contrast signals is generally of the same order as the range of the color-opponent signals.

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