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Bayesian model of the staircase Gelb effect

Sarah R. Allred Department of Psychology, University of Pennsylvania

Lynn J. Lohnas Department of Neuroscience, University of Pennsylvania

David H. Brainard Department of Psychology, University of Pennsylvania

Abstract

Introduction: For perceived lightness to be a useful guide to object identity, it should correlate with physical surface reflectance across changes in viewing conditions. Most vision scientists agree that lightness perception involves the resolution of ambiguity inherent in the retinal image. There is less consensus about how to frame models of this process. We have found it clarifying to develop ideal observer models. These models estimate illuminant intensity and surface reflectance from the image data and link the estimates to psychophysical performance. Here we show that such a model can account for the staircase Gelb effect (Cataliotti & Gilchrist, 1995). This effect has been presented as a challenge for ideal observer models, because simple variants of these models to not predict it.

Methods: We simulated a world with a single row of eleven pixels. The retinal image was obtained as the pixel-by-pixel product of illuminant intensity and surface reflectance. The statistical ensembles of illuminants and surfaces were each modeled as a multivariate Gaussian distribution specified by the pixel mean, the pixel variance, and the correlation between neighboring pixels. We estimated illuminant intensity and surface reflectance at each pixel by maximizing the full posterior distribution (computed using Bayes' rule). Importantly, our implementation allowed both illuminant intensity and surface reflectance to vary over space.

Results: In the staircase Gelb effect experiment, a series of grayscale surfaces are illuminated by an intense spotlight. The data demonstrate range compression, since the actual reflectance range of the surfaces (~0.03-0.9) is far greater than the corresponding range of observed lightness matches (~0.3-0.8). For these conditions, range compression emerged naturally from our model: the estimated surface reflectances showed range compression similar to the experimentally observed matches.

Conclusion: Ideal observer models of lightness perception can account for the

phenomenon of range compression.

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