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# A deep convolutional neural network trained to infer surface reflectance is deceived by mid-level lightness illusions

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## Abstract

A long-standing view is that lightness illusions are by-products of strategies employed by the visual system to stabilize its perceptual representation of surface reflectance against changes in illumination. Computationally, one such strategy is to infer reflectance from the retinal image, and to base the lightness percept on this inference. CNNs trained to infer reflectance from images have proven successful at solving this problem under limited conditions. To evaluate whether these CNNs provide suitable starting points for computational models of human lightness perception, we tested a state-of-the-art CNN on several lightness illusions, and compared its behaviour to prior measurements of human performance. We trained a CNN (Yu & Smith, 2019) to infer reflectance from luminance images. The network had a 30-layer hourglass architecture with skip connections. We trained the network via supervised learning on 100K images, rendered in Blender, each showing randomly placed geometric objects (surfaces, cubes, tori, etc.), with random Lambertian reflectance patterns (solid, Voronoi, or low-pass noise), under randomized point+ambient lighting. The renderer also provided the ground-truth reflectance images required for training. After training, we applied the network to several visual illusions. These included the argyle, Koffka-Adelson, snake, White's, checkerboard assimilation, and simultaneous contrast illusions, along with their controls where appropriate. The CNN correctly predicted larger illusions in the argyle, Koffka-Adelson, and snake images than in their controls. It also correctly predicted an assimilation effect in White's illusion. It did not, however, account for the checkerboard assimilation or simultaneous contrast effects.

These results are consistent with the view that at least some lightness phenomena are by-products of a rational approach to inferring stable representations of physical properties from intrinsically ambiguous retinal images. Furthermore, they suggest that CNN models may be a promising starting point for new models of human lightness perception.