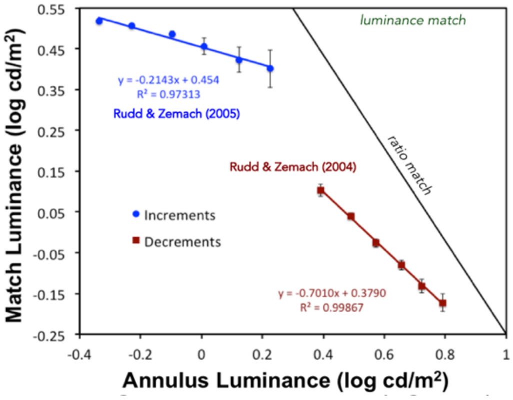
Known asymmetries in lightness vs darkness induction magnitudes play a significant role in contemporary theories of lightness (perceived surface reflectance). Until recently, a standard dogma in the field held that the lightness of a surface that is a luminance decrement with respect to its surround depends on its luminance ratio vis-à-vis the surround (Wallach, 1948, 1963; Gilchrist, 2006), while the lightness of increments is unaffected by the surround luminance (Gilchrist et al., 1999; Gilchrist, 2006). The latter effect has been interpreted as support for highest luminance anchoring in lightness (Gilchrist, 2006).

Recently, evidence has accumulated to suggest that the difference in the strengths of lightness and darkness induction is more a matter of degree than all-or-none. The figure at right plots average subject data from lightness matching experiments (Rudd & Zemach, 2004, 2005) in which the lightness of incremental and decremental disk targets was measured as a function of the luminance of their surrounding annuli. Here, the appearance of decremental targets was less affected by changes in the surround than the ratio rule predicts; while incremental targets were more affected than highest luminance anchoring predicts.



To account for these and other quantitative data on lightness/darkness asymmetries, I have proposed an alternative *neural* computational model based on the idea that the visual system spatially integrates local directed changes in log luminance across space to compute lightness (Rudd, 2013, 2017). Here, I further develop this model by: 1) presenting additional neural and psychophysical evidence for the lightness computations assumed by the model; and 2) Illustrating in greater detail thus-far unconfirmed cortical computations that would have to be performed in order for the model to work as proposed.

A key assumption of the model is that the lightness/darkness asymmetries are due to differences in the visual response to increments and decrements in ON- and OFF- cells in the retina, LGN, and early visual cortex. These neural asymmetries, in turn, produce asymmetries in the responses of oriented contrast (e.g. edge) detectors at a subsequent stage of processing, which, in turn, explain asymmetries between percepts of lightness and darkness that are neurally computed at a higher stage of the ventral stream (probably in V4 or TEO).

More specifically, the model assumes that the responses of ON cells are described by a Naka-Rushton functions that can be approximated for sufficiently large surround luminances as a power law of the form $R = \left(\frac{\Delta L_c}{L_s}\right)^{1/3}$ the responses of OFF cells are described by a similar function of the approximate form $R = \frac{L_S}{\Delta L_c}$ where ΔL_c is the incremental luminance in the cell's receptive field center versus its surround, and L_s is the luminance in the cell's receptive field surround. $\Delta L_c \cong L_c$ for large L_c. These neural responses to local incremental and decremental luminance are combined to produce asymmetric 2D oriented receptive fields in V1 (suitable for detecting edges) that, in turn, feed object-centered border detector neurons in V2. The outputs of the border neurons are then log-transformed and summed spatially to produce a neural representation of the achromatic color (i.e. lightness) of a disk in a disk-annulus display (for example) of the form

$$\Phi_D = \omega_1 g_1^{cp}[D - A]^+ + \omega_1 g_2^{cp}[A - B]^+$$

where Φ_D is the disk lightness; ω_1 and ω_2 are spatial weights that depend only on the distance from the receptive field center of the neurons that perform the spatial integration of the early edge responses generated at the inner and outer edges of the annulus; g_1^{cp} and g_2^{cp} are neural gains applied to those edges, which depend on the edge contrast polarity (*cp*) and are related to the exponents of the power laws describing the ON and OFF neurons; *D*, *A*, and *B* are the luminances (in log units) of the disk, annulus, and background fields; and the function [ ]+ denotes half-wave rectification.

I will further discuss how different Naka-Rushton exponents observed in primate and cat may relate to function. The approximate squaring operations seen in cat (Pons et all., 2017) make sense for computing motion, while the cube-root compression seen in primate (Young, 1986) makes sense for mapping the high-dynamic range of environmental luminances into a spike code for lightness. In closing, I will also present new 2D simulations of the lightness model's response to checkerboard inputs to show that the model can compute lightness images more complex than the simple disk/annulus patterns for which I have previously presented analytic solutions.