CEDI: A Neural Model of Colour Vision, with Applications to Image Processing and Classification

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The CEDI (Contrast Enhance / Discount the Illuminant) system models a cascade of primate colour vision cells: retinal ganglion, thalamic single opponent, and two types of cortical double opponents (Figure 1). A unified model formalism derived from psychophysical axioms produces transparent network dynamics and principled parameter settings. CEDI fits an array of physiological data for each cell class,[1-4] and makes testable experimental predictions. Properties of the feature vector components in CEDI are compared with properties of corresponding components in the Neural Fusion Module,[5] and computational capabilities of these two models are examined on satellite imagery tasks. The satellite benchmark testbed demonstrates the marginal computational utility of each of the four CEDI model cell types. This analysis is carried out in the context of a large-scale research program that is integrating cognitive and neural systems derived from analyses of vision and recognition to produce both biological models and technological applications.[6]

Figure 2(a) summarizes, for red/green colour combinations, arrays of physiological recordings from each of the four cell types modeled by CEDI. For example, square 4 shows responses to a black spot surrounded by a red annulus. For this input, a retinal R cell has a maximally negative center response (black); an RG double opponent I cell has an intermediate negative center response (dark grey); and an RG double II cell has in intermediate positive center response (light grey). Center responses of the CEDI model (Figure 2(b)) exactly match all those found in the literature, except for

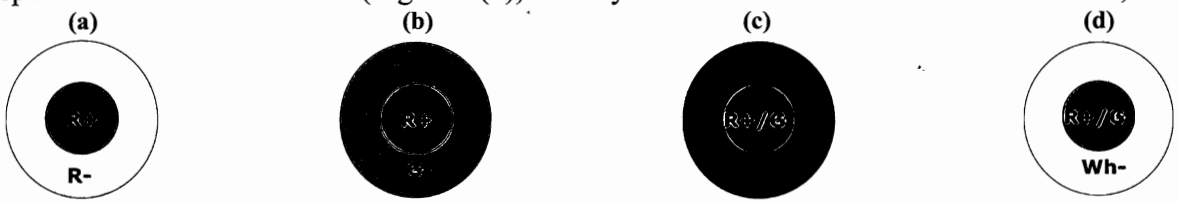

Figure 1: Receptive fields of (a) retinal, (b) thalamic single opponent, and (c, d) cortical double opponent colour cells, illustrated here for red/green (R/G). (a) Retinal cells exhibit a center-surround spatial antagonism derived from their cone inputs. The ideal stimulus for the red ON-center, red OFF-surround cell is a red center surrounded by anything but red.[1] (b) Thalamic single opponent cells exhibit a center-surround chromatic antagonism with red-green (or blue-yellow) colour pairs. The ideal stimulus for the red ON-center, green OFF-surround cell is a red center surrounded by anything but green.[2,3] Note that "red center" here means "any colour with a maximal red component," and "anything but green" means "any colour without a green component." Thus, for example, a white ON-center, black OFF-surround would also be expected to produce a maximal center response, as would a solid red field. (c) Double opponent I cells, popularized by Livingstone and Hubel,[2] exhibit center-surround spatial antagonism within each colour and chromatic antagonism between colours. The ideal stimulus for this red ON-center, green OFF-center cell is a red center surrounded by green. (d) Double opponent II cells, reported by T'so and Gilbert,[4] exhibit chromatic antagonism within the center and surround of the cell, and the surround is also broad-band suppressive. The ideal stimulus for this red ON-center, green OFF-center cell is a red center surrounded by black.

the double opponent II responses in squares 9 and 10. For these two cases, model predictions reverse the reported intermediate positive and negative center responses. Note that this analysis shows that the Neural Fusion "double opponent" model (Figure 2(c)) is functionally a single opponent model.

Gaps in reported data (orange squares in Figure 2(a)) correspond to CEDI model predictions (by Figure 2(b)). For example, CEDI predicts that a white spot in a green annulus (square 7) will produce strong positive center responses from R retinal and from RG double opponent II cells, baseline center responses from RG single opponent cells, and intermediate positive center responses from RG double opponent I cells.

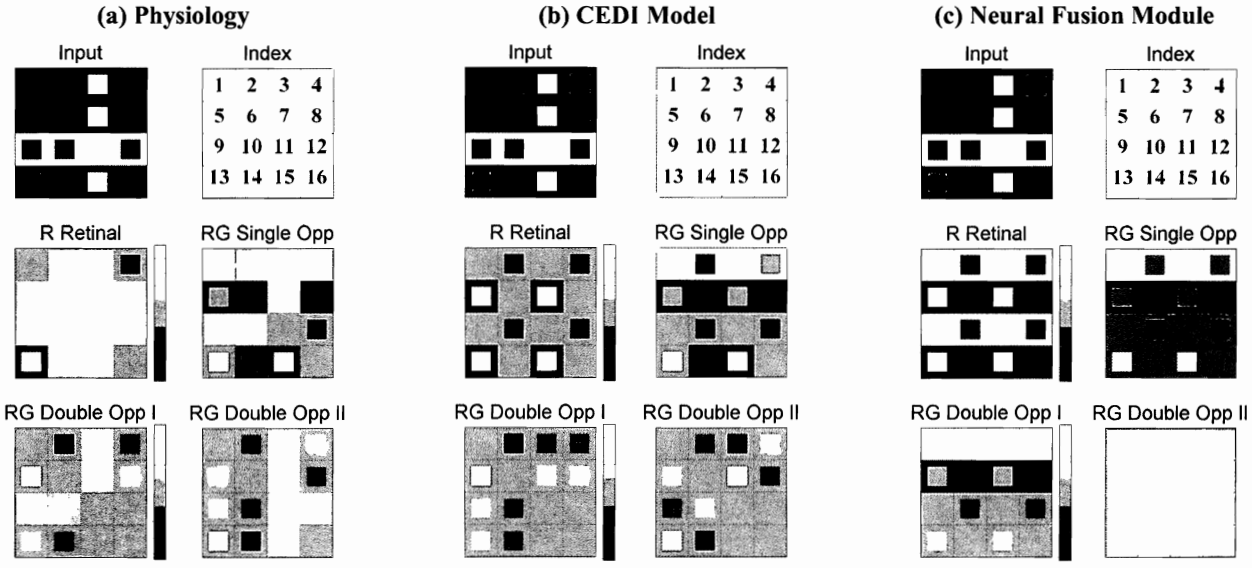

Figure 2: Response profiles of Red/Green cell types (retinal, single opponent, and double opponent I, II) from (a) physiology, (b) the CEDI model, and (c) the Neural Fusion Module. Elements of the 4x4 arrays in the top row indicate the center and surround inputs for 16 experiments for each cell type. Response bins (white=high to black=low) represent strong positive, intermediate positive, baseline, intermediate negative, and strong negative responses, respectively. Orange squares represent outcomes that are unreported (a) or not modeled (c). White inputs mix all colours maximally (R=G=1); black inputs have no colour components (R=G=0).

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