Separate normalization of ON / OFF channels is not enough to account for perceived brightness

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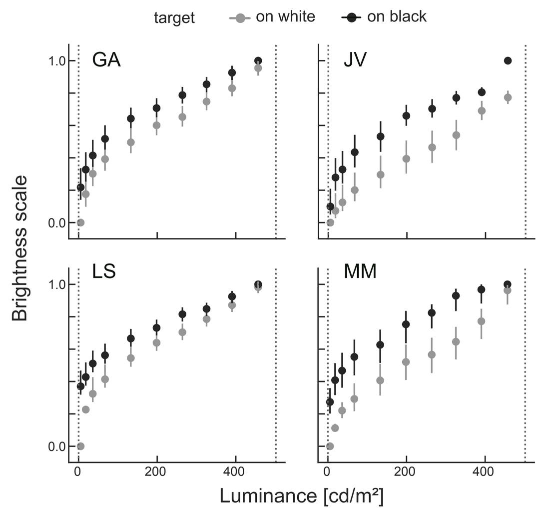
Goal

Improve quantitative predictions of image-computable models of brightness perception, by including asymmetric ON/OFF processing.

Perceived brightness scales nonlinearly with luminance in White's effect



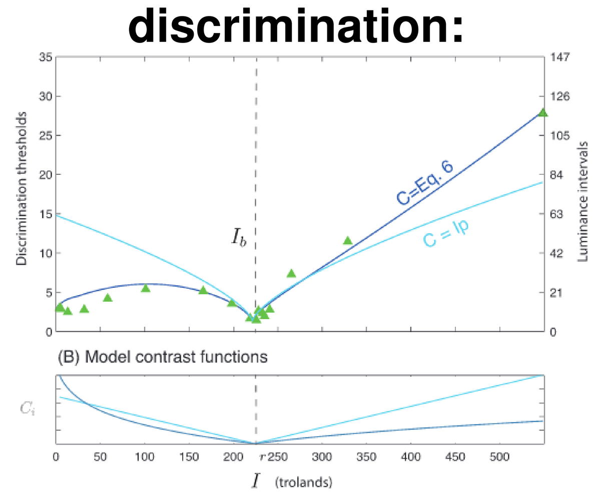
- White's effect, range of target luminances
- Estimate perceptual scales (MLCM)

- Compressive for "in black"
- S-shaped for "in white"
- Meet at the extremes

(Aguilar, Maertens, Vincent, 2022)

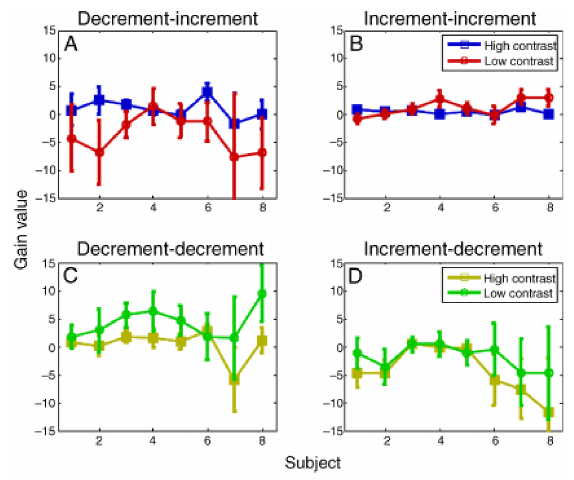
Contrast polarity: asymmetry in ON vs. OFF pathways (increments vs. decrements)

Model detection, discrimination:



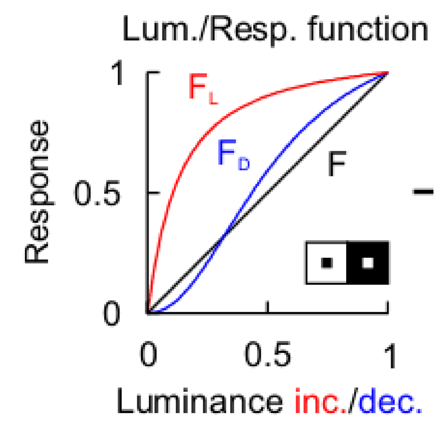
e.g., Whittle (1992); *Kane & Bertalmio (2019)*, ...

Edge-integration models:



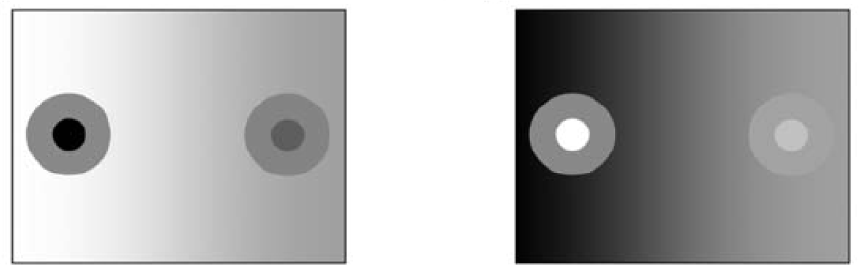
e.g., Rudd & Zemach (2007); *Vladusich, Lucassen, Cornelissen (2007)*; Rudd et al. (2023), ...

Neurophysiological models:



e.g., *Kremkow et al. (2014)*, ...

Well-defined stimuli:
with clear background, edges



Homuncular:
explicit information about edges, background

$$W = \frac{I_p}{I_r} \text{ for decrements}$$

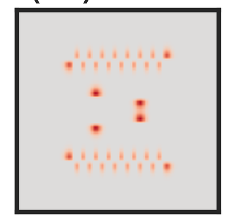
$$W = \frac{I_p}{I_b} \text{ for increments}$$

How to separate ON / OFF in image-computable models?

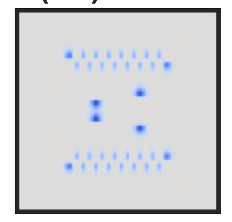
Polarity-specific normalization is not enough

2. Split +/− into "ON" / "OFF" channels

ON (+) contrast

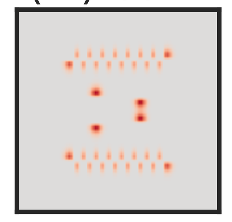


OFF (−) contrast

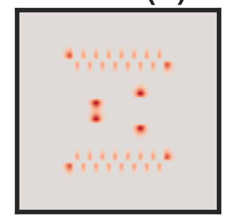


3. Rectify "OFF" channel to positive values

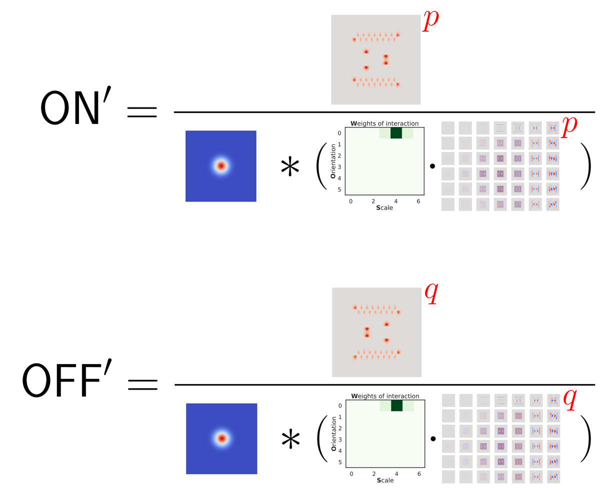
ON (+) contrast



rectified OFF (-) contrast



4. Polarity-specific nonlinear normalization



***Result:* can adjust shapes, but cannot explain scales**

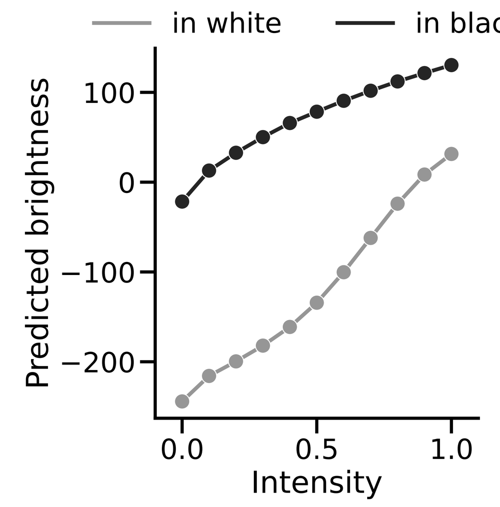
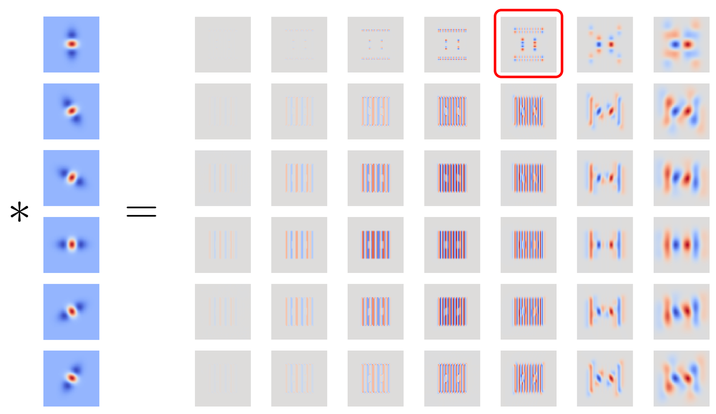


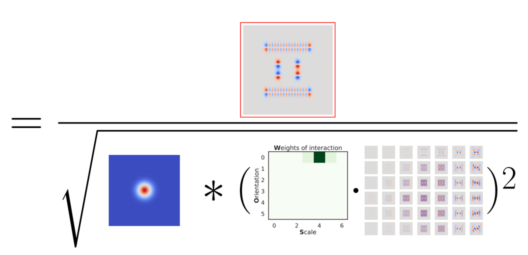
Image-computable brightness model: FLODOG

1. Filter for contrast at different orientations, spatial scales:

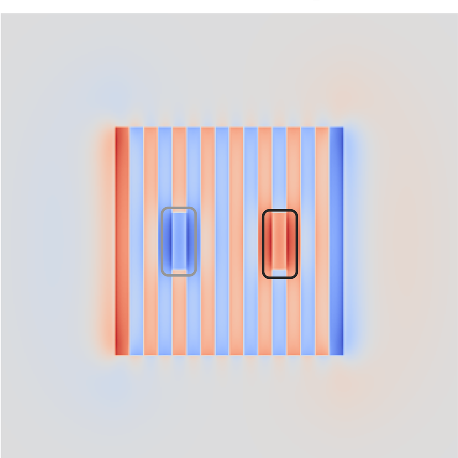


2. Normalize each channel by similar & nearby channels:

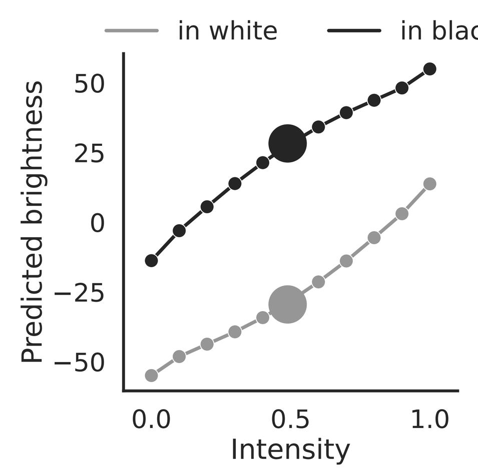
$$f'_{o,s} = \frac{f_{o,s}}{\sqrt{a_{o,s} * (\mathbf{w} \cdot \mathbf{F})^2}}$$



3. Recombine normalized channel outputs:



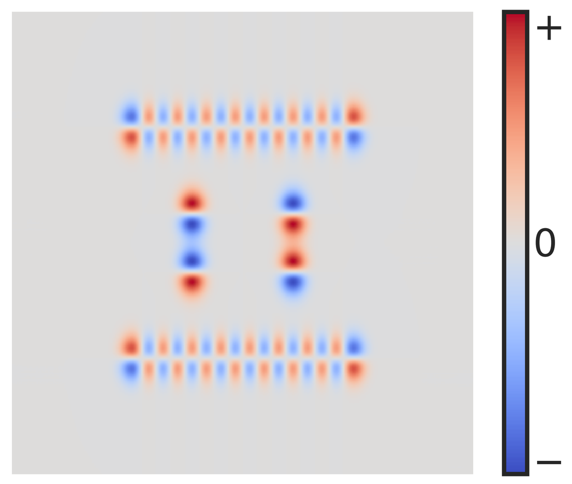
4. Readout target "brightness" for range luminances:



(Robinson, Hammon, & de Sa, 2007; Vincent, Maertens, Aguilar, 2022)

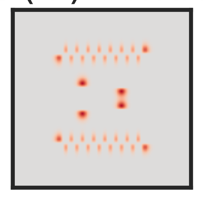
Contrast polarity in image-computable models

1. Filters produce + and − output contrast

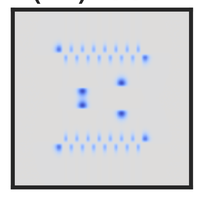


2. Split +/− filter output into "ON" / "OFF"

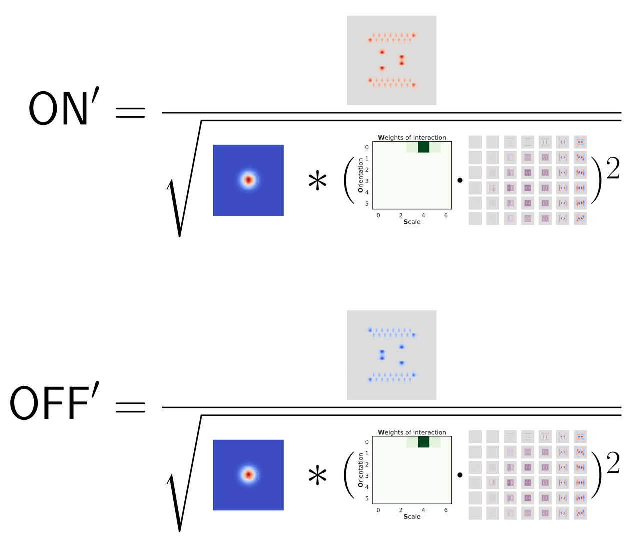
ON (+) contrast



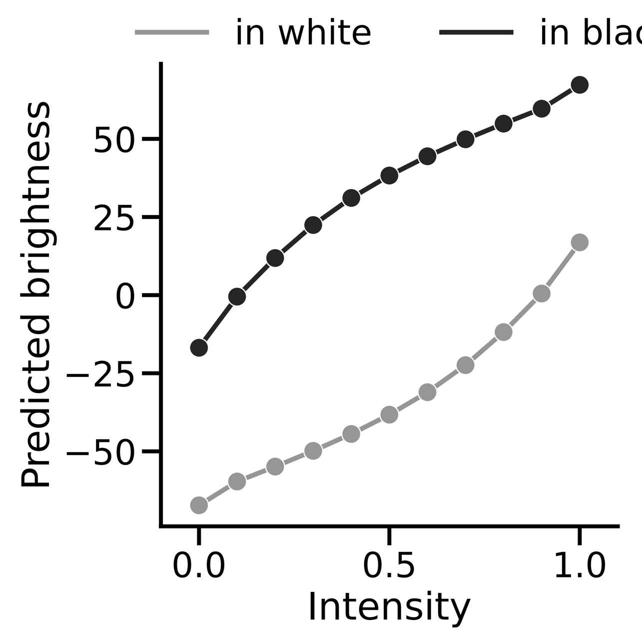
OFF (−) contrast



3. Normalize channels polarity-specific



***Result:* Polarity-specific processing based on filter-output sign should & has little effect**



Discussion

- Image-computable models can separate ON / OFF channels everywhere in arbirtrary image, as sign of filter output
  - compared to most previous models: homuncular reasoning where model receives knowledge of contrast polarity, regions, in well-defined stimulus
- Asymmetric nonlinearity in ON / OFF channels not enough to predict perceptual brightness scales
  - shapes don't match; scales don't meet at extremes
  - at least for White's effect; compare with simultaneous contrast & assimilation effects
- Asymmetric processing of ON / OFF signals (positive / negative contrast) is candidate mechanism for explaining perceptual brightness scales
  - additional processing / normalization required

References

1. Aguilar, Maertens, Vincent (2022)
2. Robinson et al. (2007)
3. Whittle (1986, 1992)
4. Vladusich, Lucassen, Cornelissen (2007)
5. Kane & Bertalmio (2019)
6. Rudd et al. (2023)

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