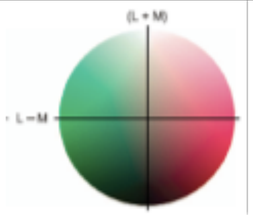

Are eye movements necessary for contrast detection?

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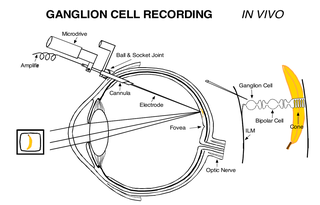


Introduction

- We first replicate older results that the Temporal Contrast Sensitivity Function (TCSF) for achromatic stimuli is low-pass against mean-level backgrounds, but band-pass against dark or bright surrounds (Kelly, 1971; Spehar & Zaidi, 1997).
- We show that this result also holds for purely chromatic modulations against equiluminant surrounds.
- We investigated the neural substrates for the two results at the retinal ganglion cell level.

Psychophysical Experiment

- Central Disk modulated at 3 possible frequencies (0.24 Hz, 2.4 Hz, 24 Hz), along Light-Dark or equiluminant Red-Green (L-M) axis to isolate M and P cells (Derrington et al, 1984; Sun et al 2006).
- Central target disk embedded in two Surround conditions: 1) Mean-level Surround, 2) Extreme surround (Dark for LD and Red for RG),
- Thresholds measured with double-random, interleaved staircases in a 2IFC paradigm.

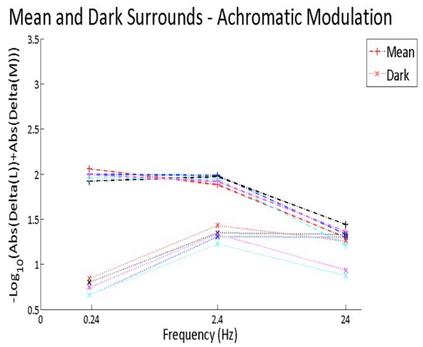
Achromatic Sinusoidal Modulation on Mean Surround

Achromatic Sinusoidal Modulation with a Contrast Pedestal on Extreme Surround

Chromatic Sinusoidal Modulation on Mean Surround

Chromatic Sinusoidal Modulation with a Contrast Pedestal on Extreme Surround

Psychophysical Results



Achromatic and chromatic results show similar effects of surround conditions:
1) Mean Surrounds – Low Pass
2) Extreme Surrounds – Band Pass

Possible Explanations

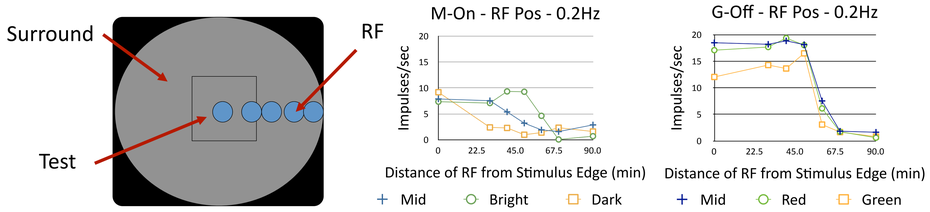
1) Low-Pass LD Contrast Mechanisms: Revealed by the thresholds on the mean surround. Presence of the contrast pedestal decreases contrast sensitivity (response saturation) leading to detection by band-pass luminance mechanisms.

2) Band-Pass M-cells: Small eye movements drag ganglion cell receptive fields across stimulus edges, creating sharp transients that contain high frequencies. With mean–surrounds, transients are only created in the test interval, but with the large pedestal, transients have similar effects in the two intervals.

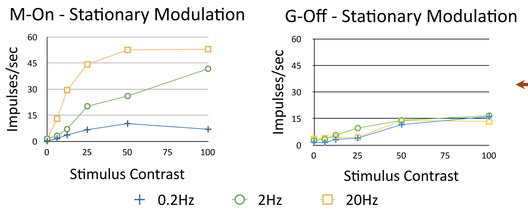
3) Given that P-cells are low-pass, the above explanations can not apply to the chromatic results.

Physiological Results

- Macaque ganglion cells were recorded in vivo. Square patches were modulated along the LD or RG axes and could be stationary or moved across the RF. They were presented in the same surround conditions as the psychophysical experiment.
- M and P cells were tested with stationary and jittered presentations. The jittered presentations simulated the effects of eye movements.
- Responses were mapped for location of ganglion cell RFs with respect to the stimulus edge.
- Responses do not depend on the surround condition and no increased response is seen when the RF is placed over a stationary modulating edge.



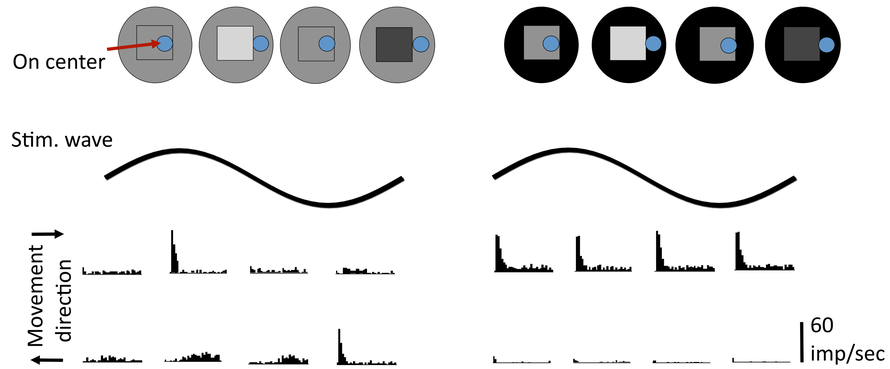
- Both M and P cells respond weakly (4-9 impulses/sec) to low temporal frequency stationary modulations that cover the RF, indicating that ganglion cell center-surround structure alone is not sufficient for mediating the psychophysical task. In presenting stationary stimuli, we also confirm that M cells are band-pass and P cells are low-pass.



The response curves of M cells are strongly band-pass, but P cell response curves are low-pass.

These results indicate that low-pass contrast mechanisms cannot explain the psychophysical results!

- To simulate microsaccades, the stimuli were moved at four different phases of the modulation (0º, 90º, 180º, and 270º) at a jump size of 30 min. The jumps passed the stimulus edge over the cell's RF.
- On the mean surround, at the phases of appropriate contrast, jumps produced high temporal frequency transients, causing large spike bursts. On the extreme backgrounds, the strength of the spike bursts is independent of the phase of the target modulation. Such responses cannot support psychophysical detection



Discussion

- The responses of M and P cells to stationary targets do not match with the results of the psychophysical experiment: no edge effects are observed.
- Achromatic TCSFs of human observers are low pass on mean surrounds and band pass on extreme surrounds. Since the response curves of M cells are band pass for stationary modulations, the introduction of high frequency transients by eye movements generates strong responses on the mean surround and these can mediate detection. The transients are not useable on the extreme surrounds.
- Chromatic TCSFs are low pass on mean surrounds and band pass on extreme surrounds, but P cell response curves are low pass for stationary modulations. Thus, the change of surround condition should not have much of an effect on the response of P cells and the response curves should remain low pass. For chromatic stimuli, this means that high frequency transients should make psychophysical response curves more low pass on mean surrounds and leave them unchanged on extreme surrounds.
- It is difficult to explain the surround effects on chromatic TCSFs in terms of P cell responses.

Future Work

- M and P cells were also presented with modulating, jumping stimuli of different contrasts.
- We are in the process of performing neurometric analyses on the M and P cell spike train responses to these stimuli.

Conclusions

- The effect of surround level on contrast detection is not explainable by low-pass contrast mechanisms or any mechanism that depends solely on a stationary stimulus.
- Shifts of the retinal image introduce high frequency transients and help with contrast detection.

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