# Does Spatially Homogeneous Color Stimulation Produce a Single Response Point within the Physiological Cone Excitation Space?

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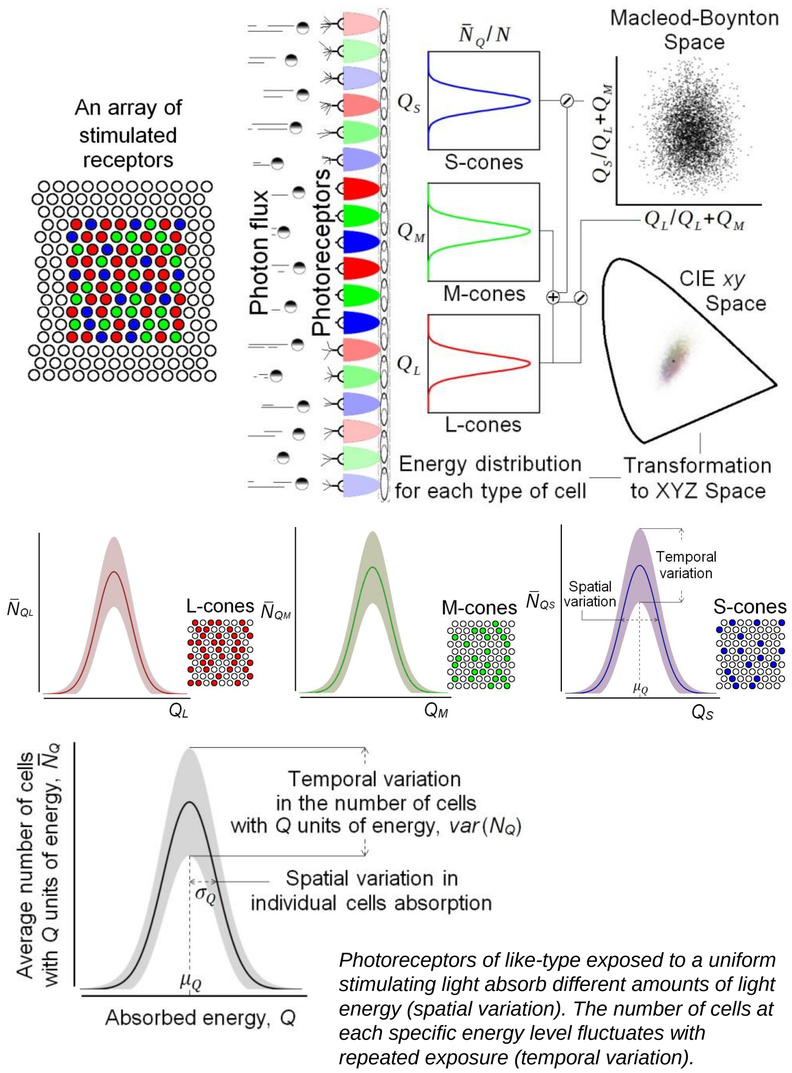
## Introduction

Fluctuation in the number of photons absorbed by a cell exposed to a monochromatic light (Geisler, 1989; Rieke & Baylor, 1998) introduces both spatial and temporal variation.

**Spatial:** When a population of cells is exposed to uniform multi-wavelength light, not all cells absorb the same amount of energy. **Temporal:** When those cells are exposed repeatedly to the same light, the actual number of cells at a given energy level varies.

Our goal is to characterize such spatiotemporal variation in terms of the distribution of cells across energy levels as opposed to the distribution of photons absorbed by a cell.

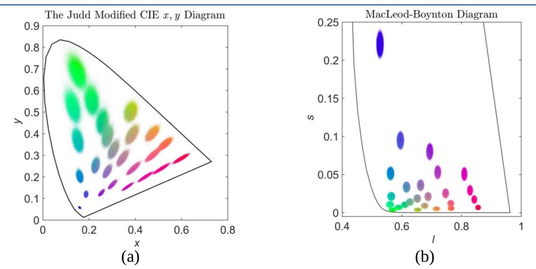
## Model




*Photoreceptors of like-type exposed to a uniform stimulating light absorb different amounts of light energy (spatial variation). The number of cells at each specific energy level fluctuates with repeated exposure (temporal variation).*

## Distribution of Cone Excitations

Due to spatial variation in absorption by individual cells, stimulation produces a distribution of responses within cone excitation space. This uncertainty due to spatial variation in absorption may influence the human color discrimination performance (Pelli, 1985; Vorobyev & Osorio, 1998).

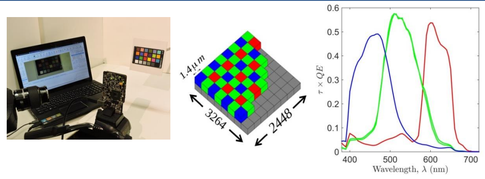



(a) *A Monte Carlo generation of excitations in cone cells exposed to the 25 MacAdam color stimuli shown within the MacLeod-Boynton diagram.* (b) A linear transformation of excitations for the same 25 stimuli to the Judd modified CIE 1931 XYZ space (Wyszecki and Stiles, 1982).

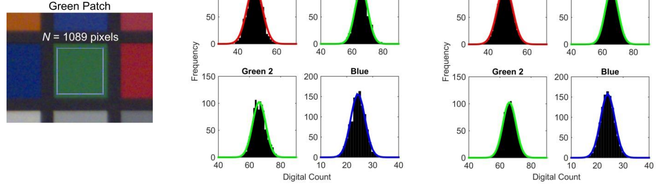
## Experiment: Performance Evaluation in a CMOS Sensor

This distribution is produced by the nature of light as it strikes an array of photosensitive cells. Thus it applies equally to living and non-living arrays of photosensitive elements.

**Material**: A CMOS sensor was exposed repeatedly to 24-patch standard color checker, illuminated by a 1000 W quartz-halogen lamp. We obtained 180 RAW images.



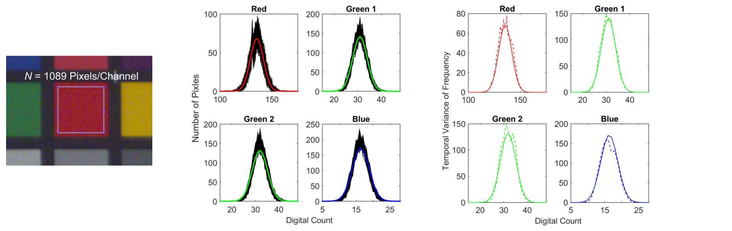

### Spatial variation in individual pixel values exposed to a uniform color patch




*Histogram from a single exposure*

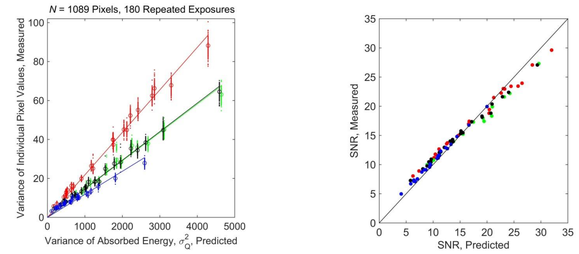
*Average of histograms from 180 trials of repeated exposure*

### Temporal variation in the number of pixels at a given value of digital count



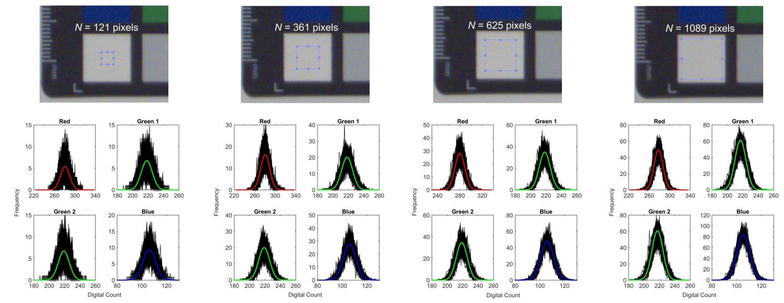

*Histograms from repeated exposure*

*Temporal variance*



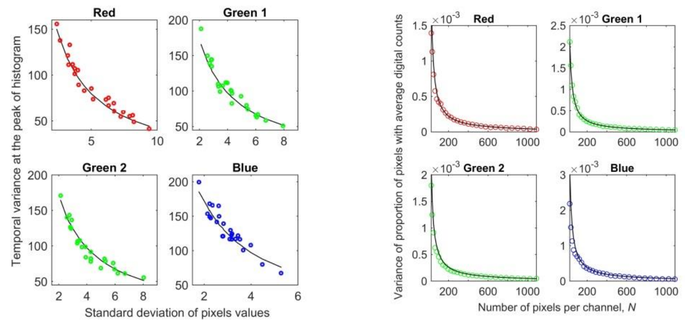

(a) *The measured variances of individual pixel values for the 24 color patches are plotted as a function of the predicted variance (the second green channel is shown by black for distinction).*
(b) *The measured SNR as a function the predicted SNR.*

### Relationship between temporal variation, spatial variation, and the number of cells




*The temporal variation becomes less appreciable when the number of cells is large*

A possible behavioral consequence of such variation is the perceptual uncertainty in perceived color for small stimuli (Hofer, Singer, & Williams, 2005; Brainard, Williams & Hofer, 2008).




*The temporal variation is reciprocally related to the spatial variation and the number of cells.*

## Summary

When a population of identical cells is exposed to uniform light, different cells absorb different levels of energy, producing a distribution of signals within cone excitation space. Our model incorporates the factor of time to reflect energy at equilibrium. For a shorter time period at higher intensities at equilibrium, spatiotemporal variation in absorption by individual cells may still influence color vision (color detection and discrimination) when the stimulus is left on, even at high levels of light intensity.

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**References**

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