

# Optimum Noise in Ganglion Cells

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**Abstract:** The nervous system is in many aspects precisely tuned to the inputs it receives to yield optimal performance. The project will research the hypothesis that noise in the nervous system is precisely tuned. The ganglion cells in the retina transfer information by rate coding. Rate coding is known to have theoretical and practical shortcomings such as slow speed of information propagation. Despite of this vision recognition can be achieved in 150msec[1]. It is now believed that the noise or the background activity can facilitate the rate coding. In this dissertation we try to prove hypothesis that not only noise is essential but also it is tuned for optimum performance of neural network.

## Introduction

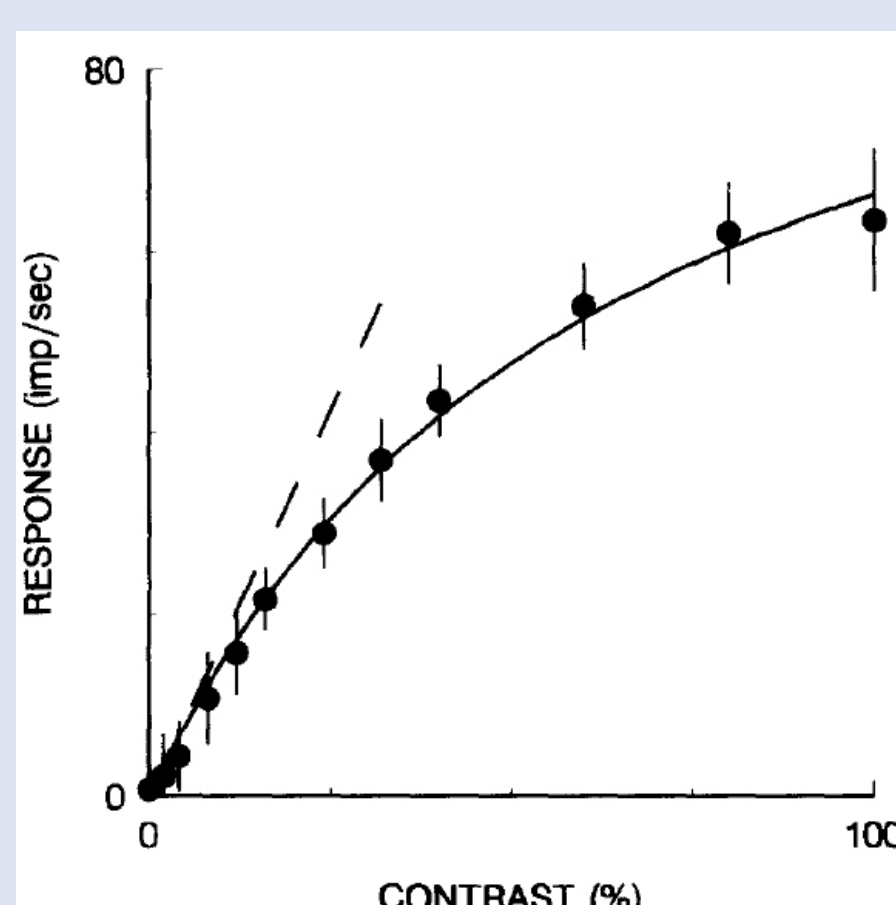
A **ganglion cell** (sometimes called a gangliocyte) is a type of neuron located in the retina of the eye that receives visual information from photoreceptors. It encodes visual information by **rate coding**, an argument that only the mean firing rate encodes information which is transferred between two neurons. The ganglion cells are exposed to large amount of noise due to synaptic background activity and spontaneous activity of cells. The rate code requires more amount of time or more number of neurons to process information. In retina where the number of ganglion cells are limited such a scheme is too inefficient for fast analog calculations. These observations lead to two questions,

- Why rate propagation with noise does not adversely affects the speed and functionality vision?
- How inherent and unavoidable noise in this kind of biological system can be seen as contributing to its vital functionality?

## Background (What do we know?)

**Rate propagation exists in ganglion cells:**

The response of ganglion cells in the primate retina to a given contrast can be described by a **Michaelis-Menten function** [2] as shown in the diagram below. The ganglion cell responses are shown as a circle with the standard deviation represented by vertical bar.



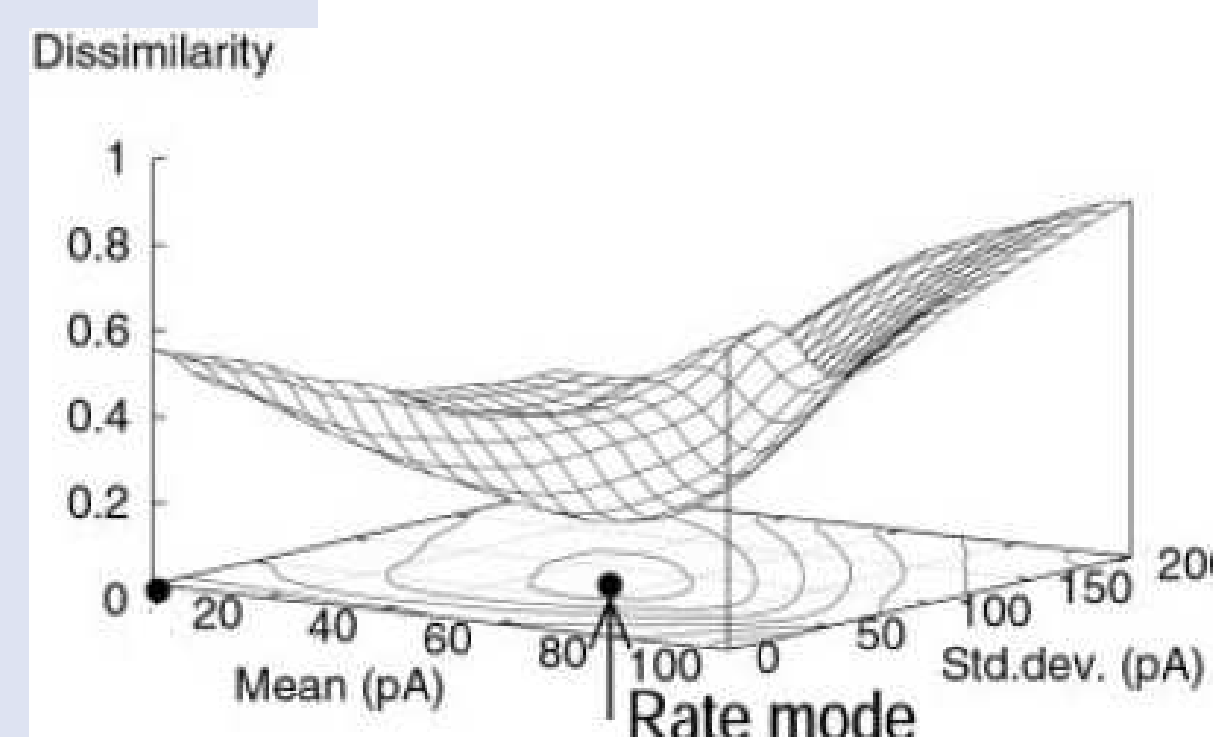
*The solid line represented the theoretical Michaelis-Menten function curve. This goes through all the data points. The dotted line is initial slope of Michaelis-Menten function curve[2].*

**Noise exists in ganglion cells:** The developing retina of e.g. cats and ferrets, internally generates activity before photoreceptors have developed. This causes **retinal waves** across groups of ganglion cells in terms of noise in absence of visual input. In addition to this **synaptic background activity** such as spontaneous quantal events or input from other cells in a network maintaining an asynchronous low-activity state can also be considered as noise.

**Optimum level of noise exists:** Recent studies have shown that noise can improve the transmission of subthreshold (weak) signals in populations of neurons, e.g., if their response is pooled. In general, **the optimum noise level depends on the stimulus distribution and on the number of neurons** in the population. Since the dependence of the optimum noise level on population size is weak for large enough populations, local neural adaptation is sufficient to adjust the level of noise to its optimal value[3].

**Noise improves rate propagation:** In absence of compensatory mechanisms such as adaptation or synaptic depression, preservation of linear input output relationship is necessary in a multilayered network. A multilayered neural network without adaptation mechanism and with **noise preserves the temporal structure of original stimulus** in response[4].

**Optimum noise level exists for rate coding:** When the noise (background current) is changed in terms of its mean and SD, the dissimilarity in input and output changes. For some value of mean and SD this dissimilarity become minimum[4].



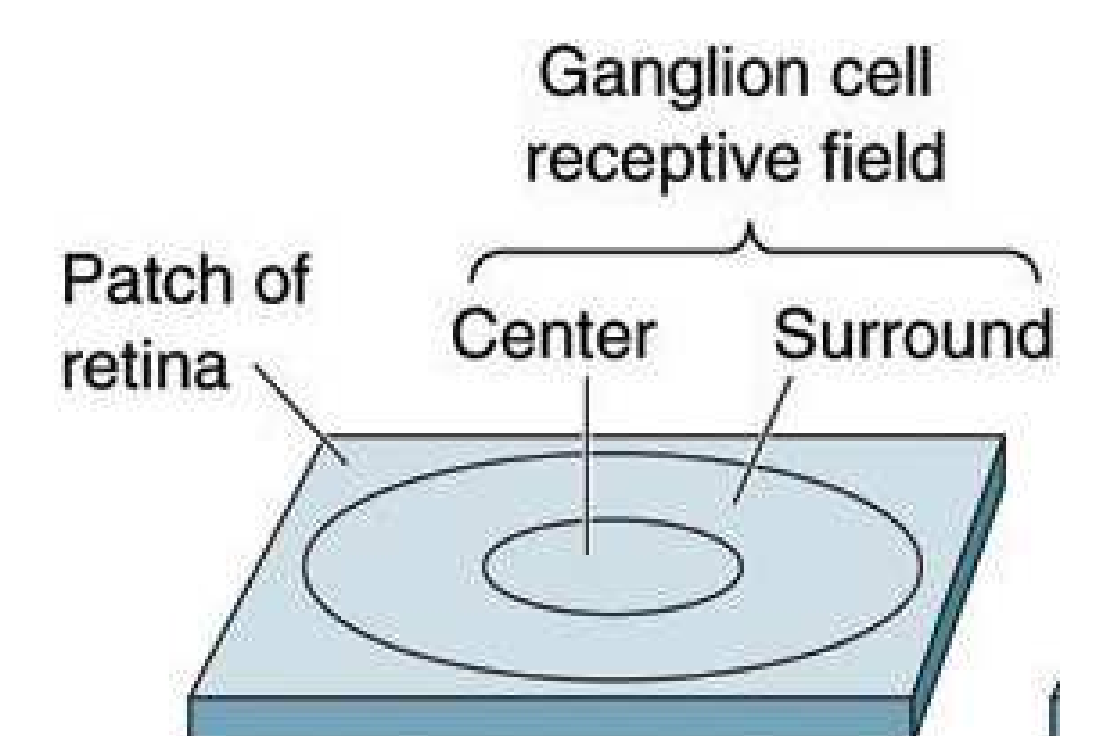
*It is shown that for rate coding dissimilarity between stimulus & response against mean and SD can be minimum for particular value of noise[4].*

## Proposed Experiments

The receptive fields of ganglion cell has an area of ON-response surround by an area OFF-response or vice versa. This is called **Center-surround antagonism**. Stimulus central on area will produce excitation and surrounding off area will cause inhibition or vice versa. Because of this unique nature of receptive fields of ganglion cells are,

- sensitive to contrast rather than intensity of light
- signalling lightness rather than brightness
- independent of the background luminance

Considering all these factors it is important to see independently how a single cell and homogenous population of cell will respond to various noise levels.



*The receptive field of ganglion cell showing center area and surround area.*

Simulations are proposed for following observations,

### Simulations for Single Cell

1. Correlation between input and output.
2. Optimum level of noise.

### Simulations for Homogenous Population of Cells

1. Relation in dissimilarities between stimulus & obtained response and current noise level.
2. Relation in various stimulus parameters (e.g. contrast, illumination intensity, size of area covered) and optimum level on noise.

## Results

**What is expected ?**

- Existence of minimum value of input output dissimilarity for optimum level of noise.
- Single value of mean and standard deviation for optimum noise level incase of network of homogenous cells.

**What this means?**

- Noise is essential element.
- Rate coding/propagation can be explained.

**Future Work**

In case of heterogeneous P,M ganglion cells there might be multiple number of values of mean and SD for optimum functionality. Because the spatial arrangement of these cells is fixed the optimum noise level may also change with the shape and region on retina where the stimulus is given.

## References

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- [3] Gregor Wenning, Thomas Hoch and Klaus Obermayer. Optimal noise-aided signal transmission through populations of neurons. *PHYSICAL REVIEW*, 68(011911), 2003.
- [4] Mark van Rossum, G.G. Turrigiano, and S.B. Nelson. Fast propagation of firing rates through layered networks of neurons. *Journal of Neuroscience*, 22:1956-1966, 2002.