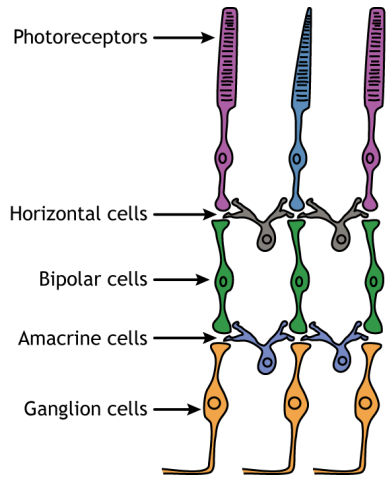
Investigation of color coding, contrast adaptation and vision encoding mechanisms using a chick retina model

Abhijith Krishnan
krishan@jncasr.ac.in

JNCASR

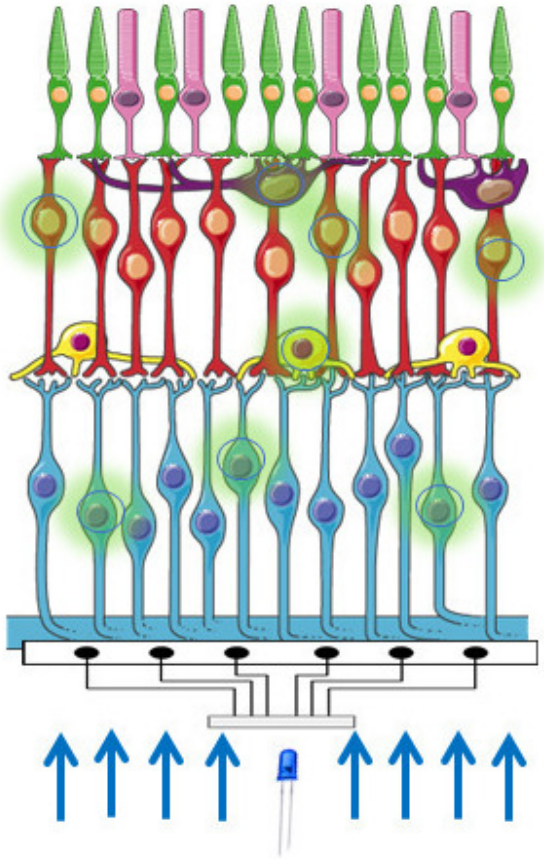
15/03/2022



Simplified schematic of the retina.[1]

- The retina is a thin slice of neural tissue found inside the eye.
- There are a total of $50 - 60$ cell types in the retina. Light is absorbed by the photoreceptors and then after processing through the different layers, the output is split into 20 different pathways and sent as spikes by retinal ganglion cells (RGCs) to higher brain regions.

[1] **https://openbooks.lib.msu.edu/neuroscience/chapter/vision-the-retina/**.



Schematic of the retina RGC side on the MEA. Light stimulation is provided from the bottom.

- The chick (representative avian species) relies highly on its daylight vision for survival. It has four different single cones providing it tetrachromic vision.
- The input to the retina is light which can be controlled using LEDs or other light sources. By using a multi-electrode array (MEA), it is possible to simultaneously stimulate the retina using light and to observe the output of a population of RGCs.
- The aim of the present study is to investigate the response of RGCs to stimuli of different colours, which will help in understanding how light falling on the retina is encoded before it is conveyed to higher brain regions.

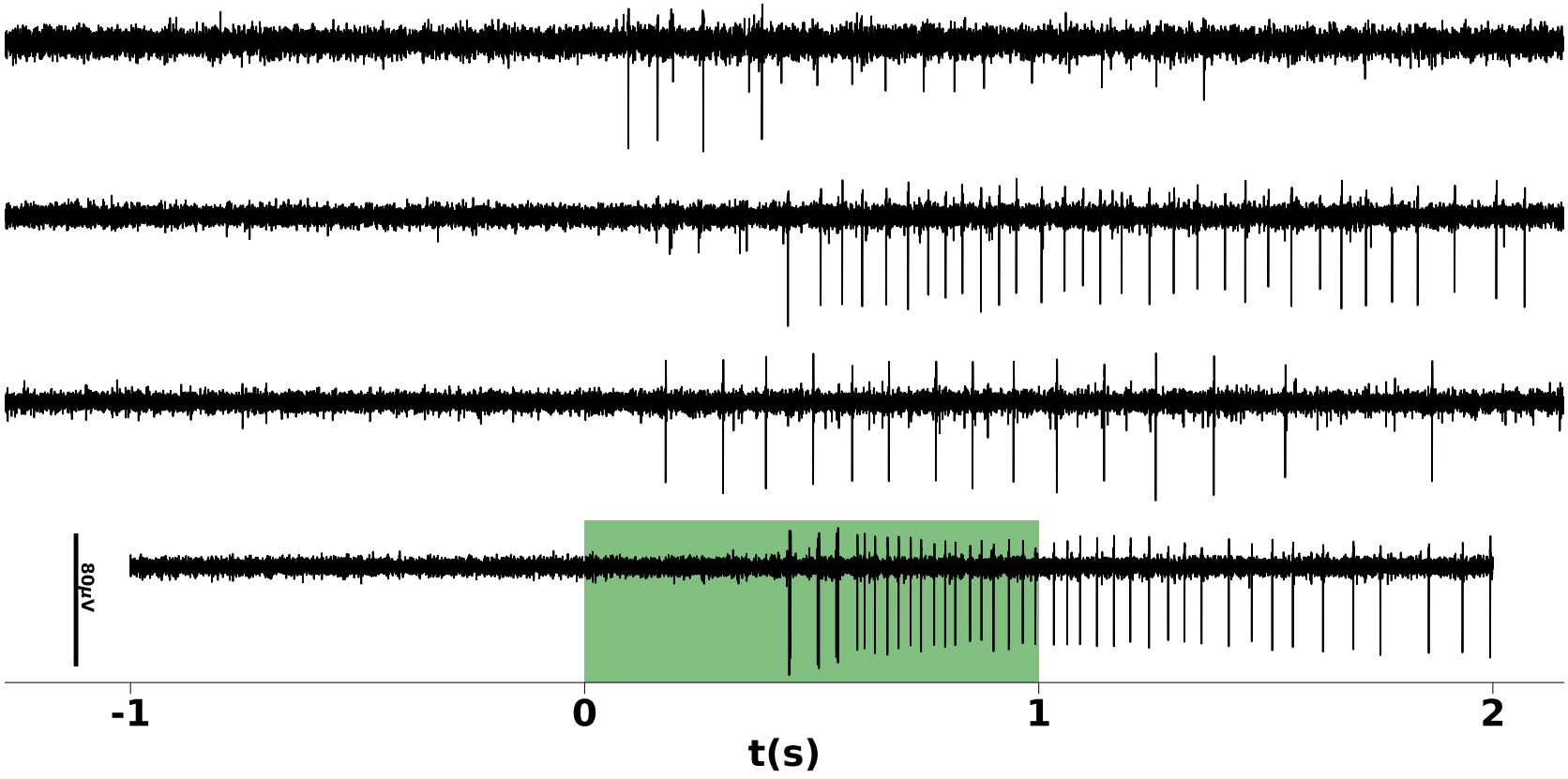
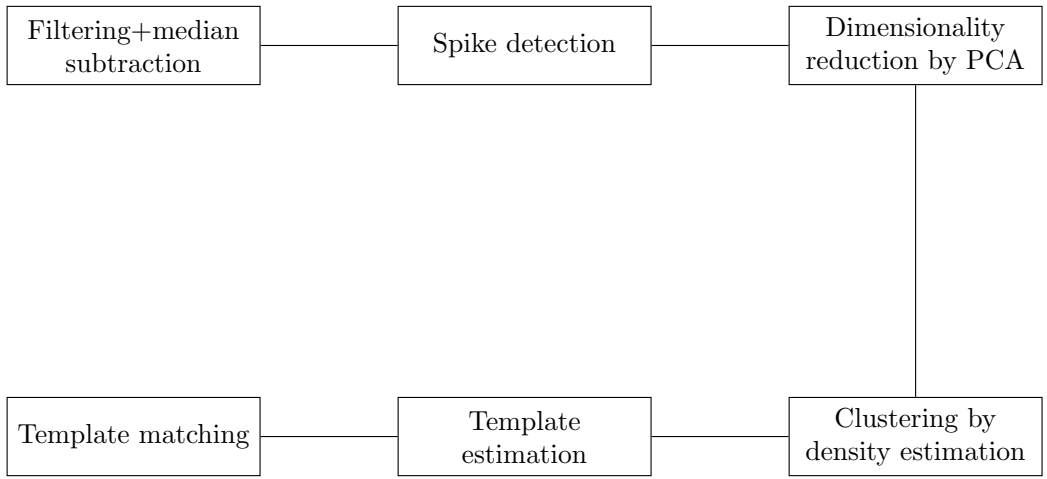


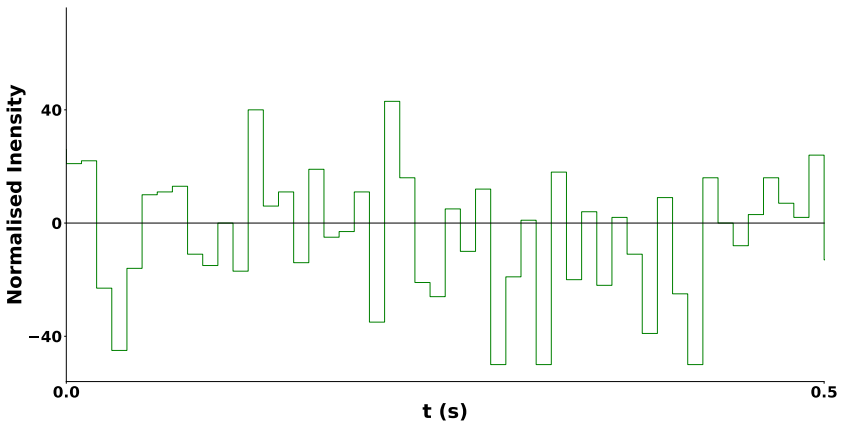
Figure: Band pass filtered data ($300 - 3000Hz$) from four electrodes from a P0 retina. The green bar represents a flash of light shown on all electrodes of the MEA.

Overview of the spikesorting procedure

Spikesorting is performed using an open source python sorter called Spyking-Circus (https://github.com/spyking-circus/spyking-circus).



Visual Stimuli



Initial 0.5s of the Gaussian full field stimuli.

- RGCs are functionally diverse with some responding to increases in contrast, some to decrease in contrast and some to both.
- To probe the temporal filtering properties of ganglion cells in further detail the light flashes from the LEDs was updated (every $10ms$, $25ms$ or $50ms$) by picking an intensity value of the LED from a Gaussian distribution of a mean and variance.
- Reverse correlation analysis was used to calculate the spike triggered average (STA) stimuli for identified neurons.

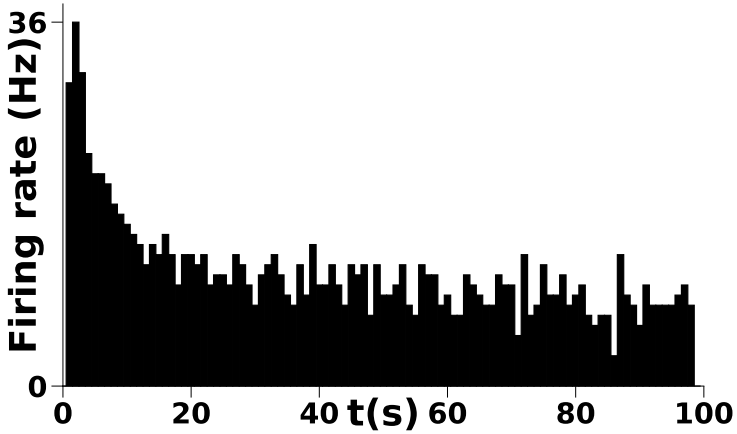


Figure: Firing rate increase due to an increase in background illumination.

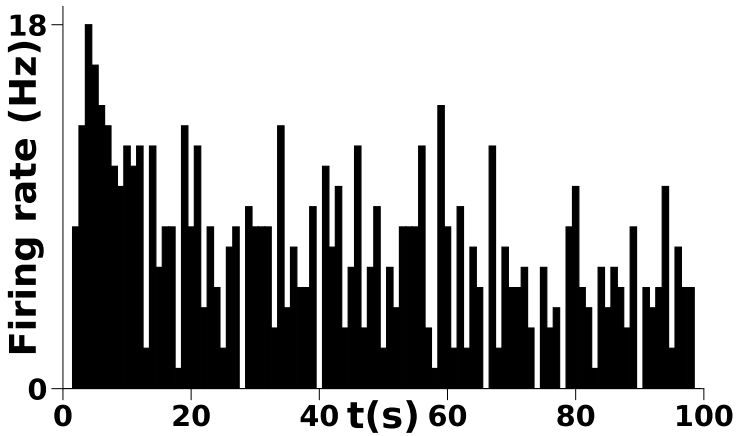
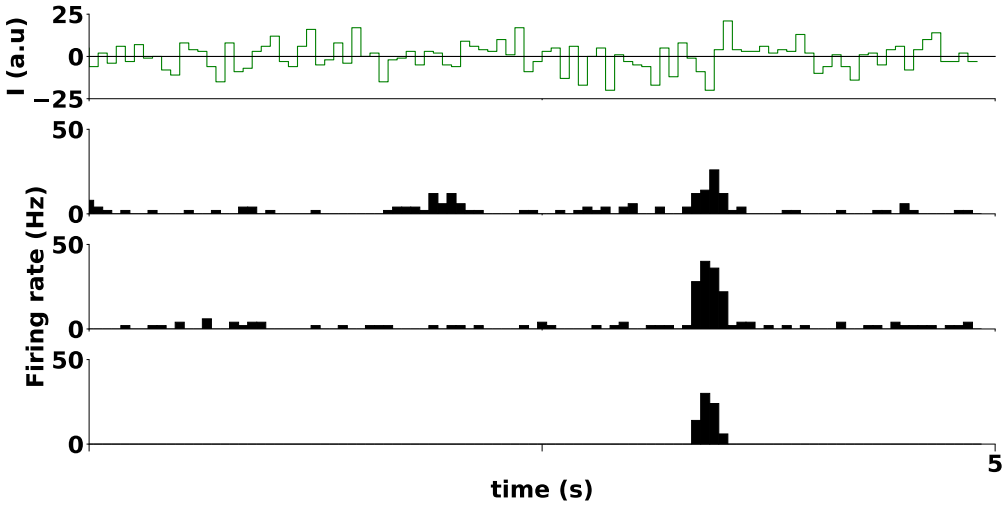


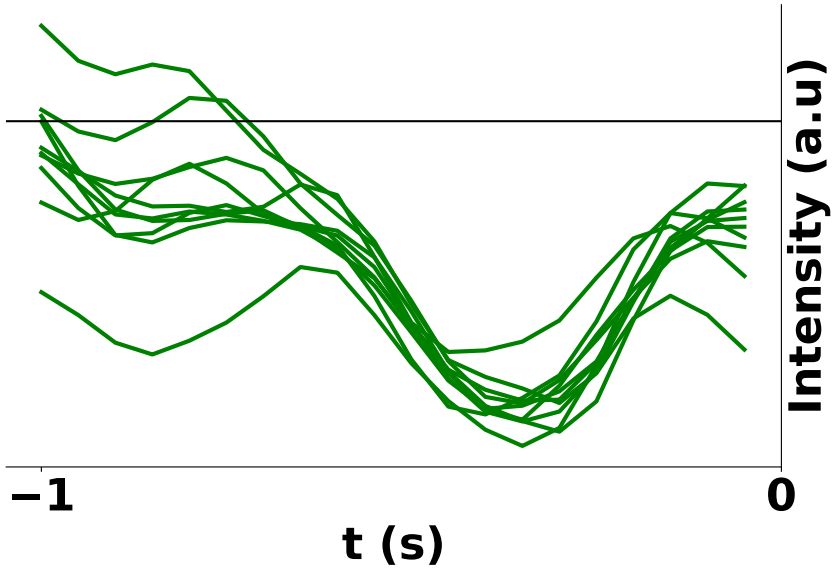
Figure: Firing rate increase after switching to high contrast stimulus.

- The retina adapts to changes in background illumination (light adaptation) as well as to increases in contrast (contrast adaptation).
- A change in background illumination can affect contrast sensitivity. When exposed to higher background illumination the contrast sensitivity of RGCs was found to increase.

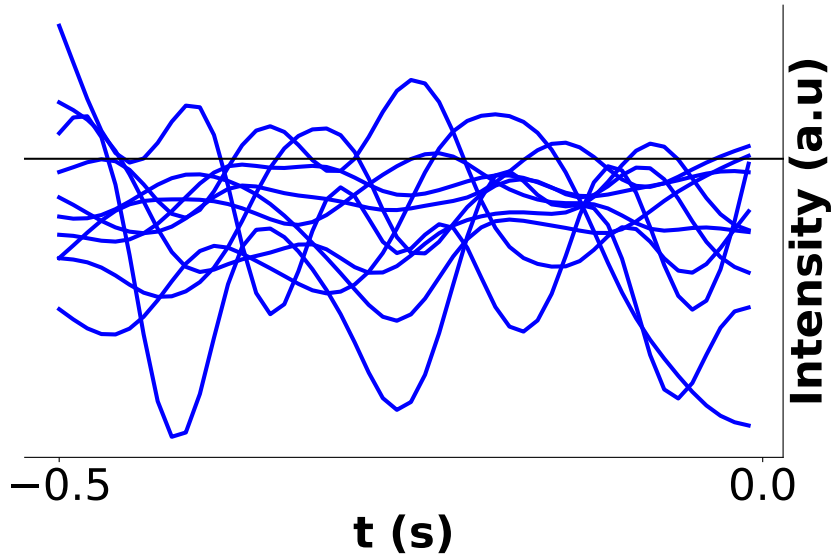


- post stimulus time histograms of 3 cells were obtained from a P2 retina for 10 repeated presentation of the same stimulus.
- The ganglion cells showed good precision with the error between trials for the spiketimes for some cells to be as low as $10ms$.

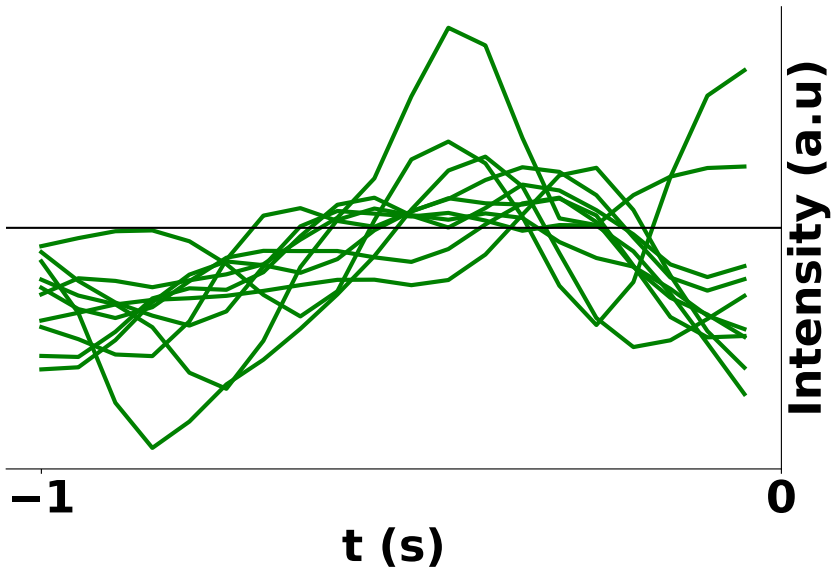
STA stimuli



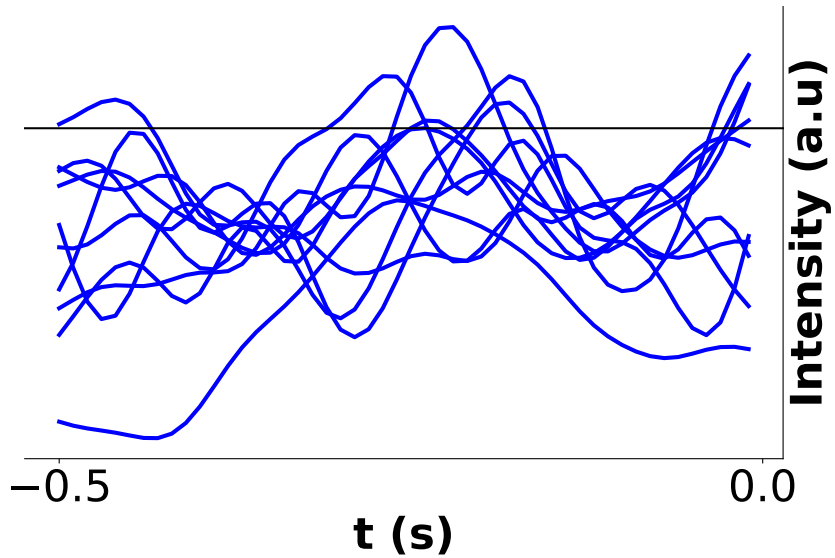
Green STA cell 1.



Blue STA cell 3.



Green STA cell 2.



Blue STA cell 4.

Colour opponent cells

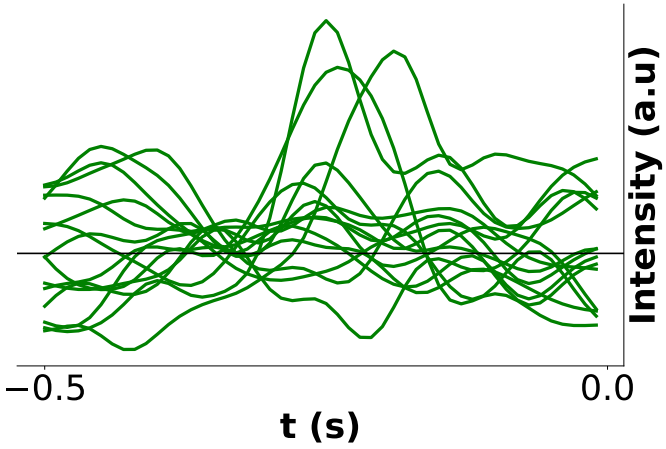


Figure: Green STA cell A.

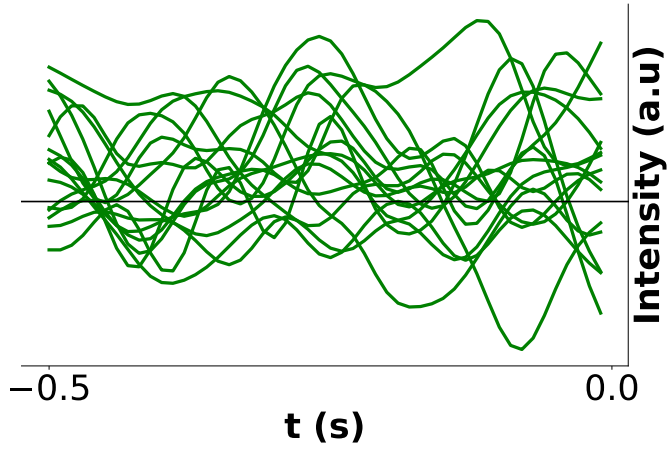


Figure: Green STA cell B.

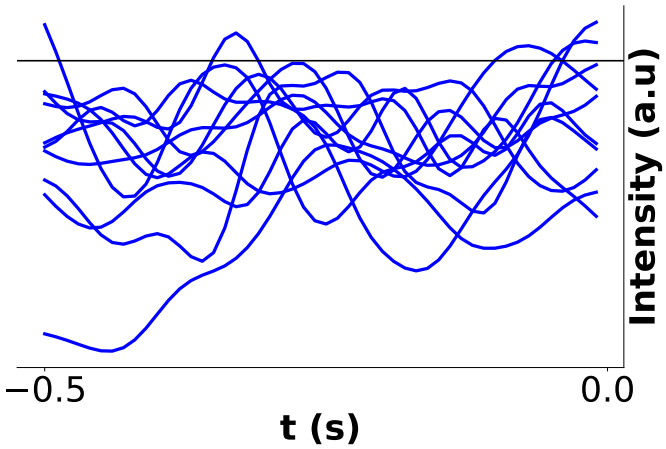


Figure: Blue STA cell A.

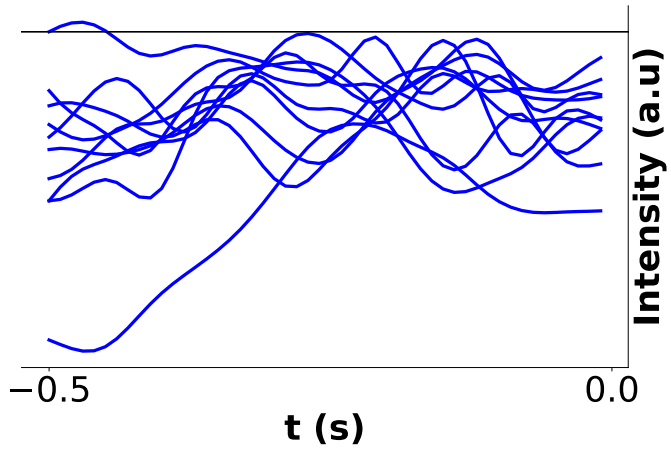


Figure: Blue STA cell B.

Summary

- Spike triggered average (STA) stimuli has been used to distinguish RGC responses in the chick retina.
- We were able to identify Green ON/Blue OFF colour opponent cells which are found in mammalian retina as well.
- This understanding of the temporal nature of RGC responses can help in developing a visual prosthetic

Thank you