Modeling LGN Selectivity and Neural Excitation Shifts Through Dynamic Activation in Curvature Detection

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Introduction

Background:

- The primate brain uses many different mechanisms to perceive the world around it — one of them being curvature detection (1, 2, 3)
- The neural processes behind curvature detection are widely unknown and complex (1, 3)

Goals:

- Creating a model that visualizes the primary curvature detection processes in the LGN and real time neural responses
- Examining patterns between inhibitory and excitatory signals in dynamic neural activation and selectivity

Results

LGN Modeling

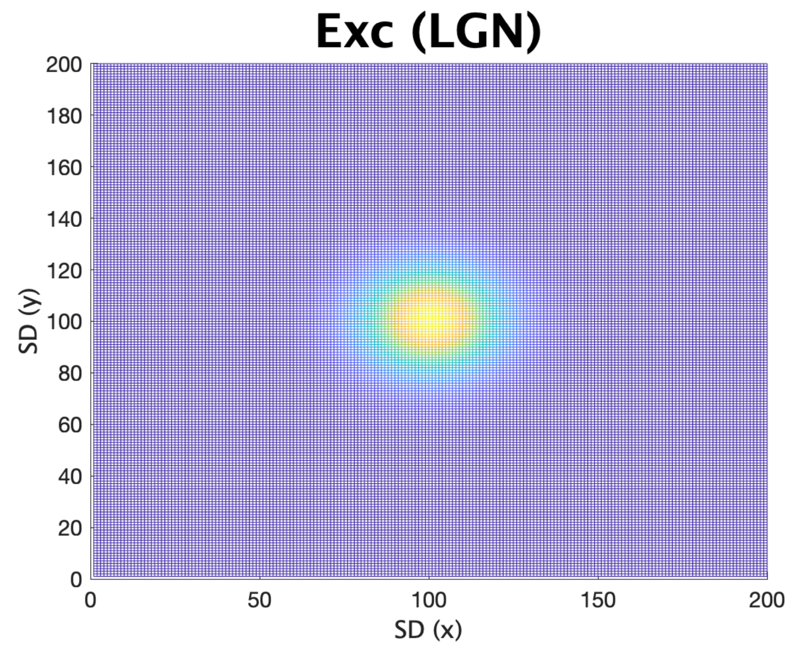

Figure 3. Visualization of excitatory kernel for LGN

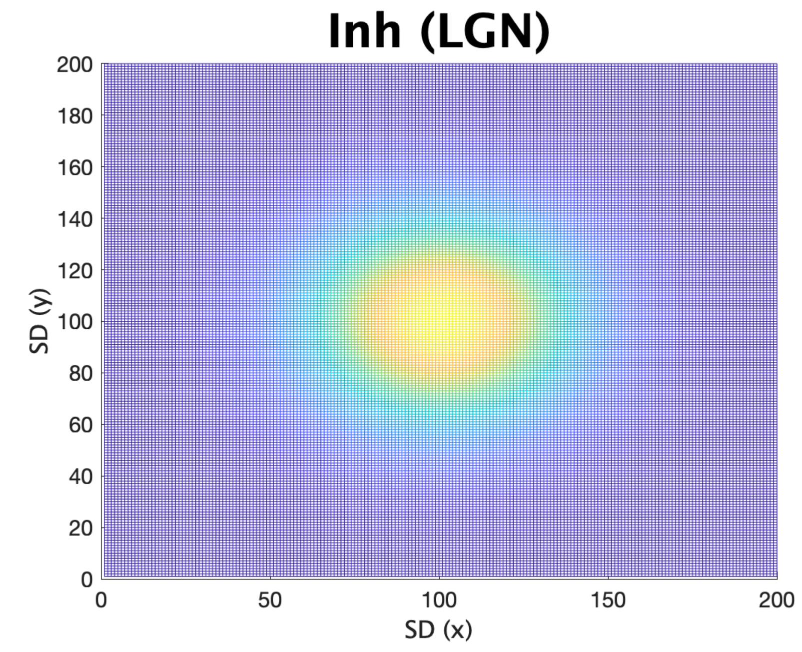

Figure 4. Visualization of inhibitory kernel for LGN

Dynamic Activation

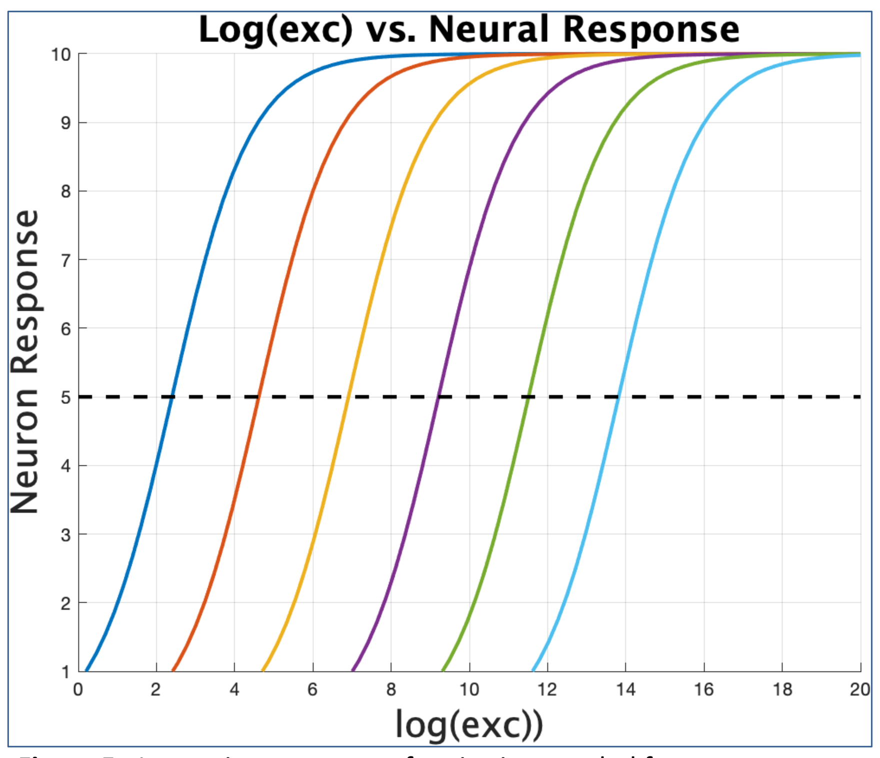

Figure 5: Increasing amounts of excitation needed for a response

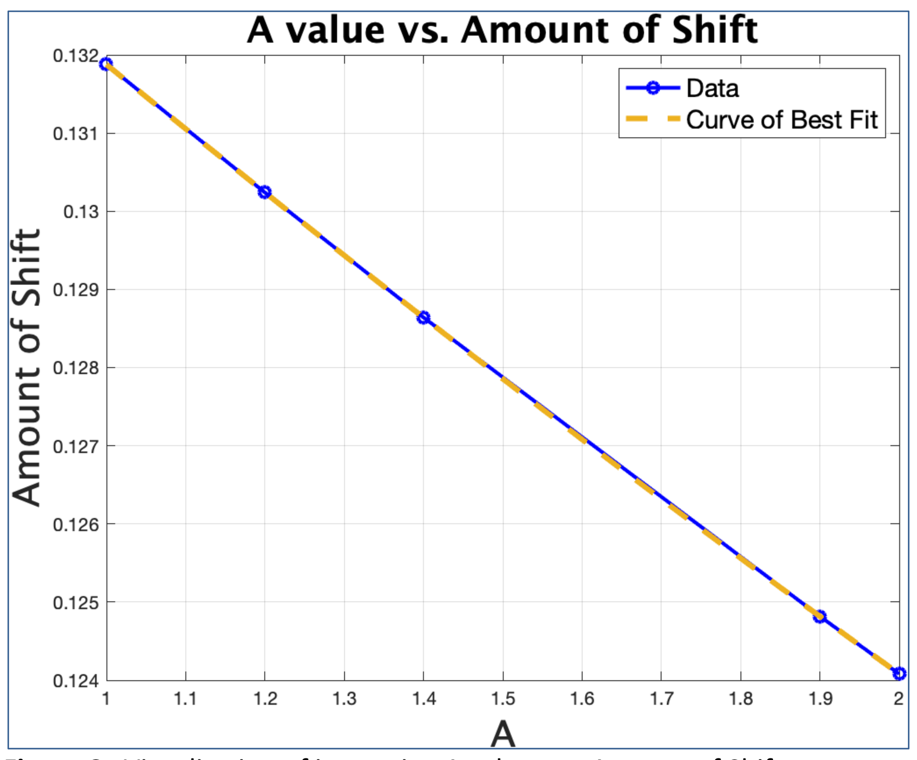

Figure 6: Visualization of increasing A values vs. Amount of Shift

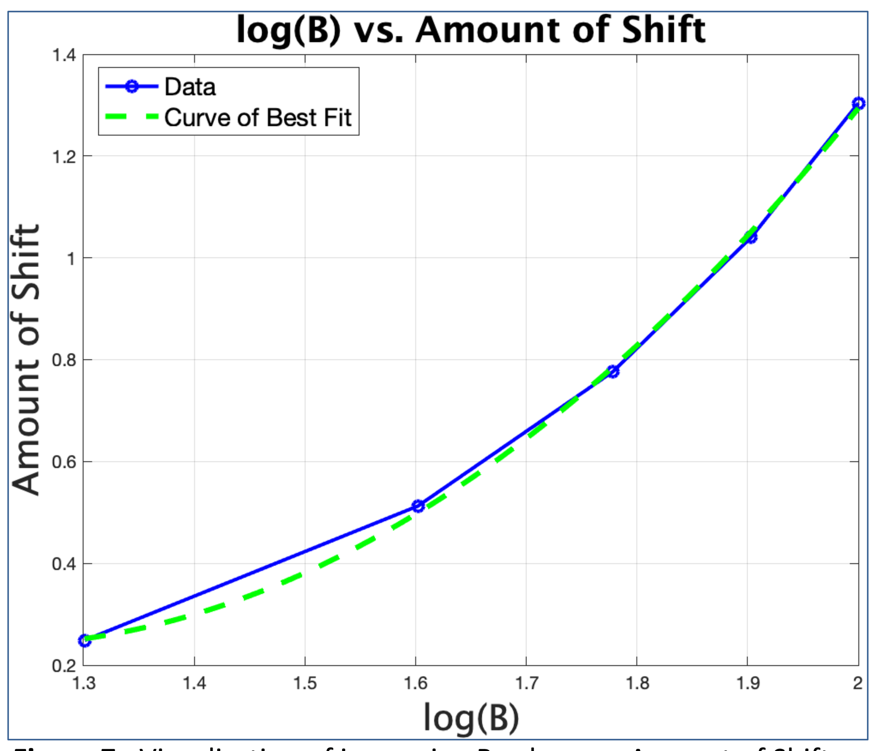

Figure 7: Visualization of increasing B values vs. Amount of Shift

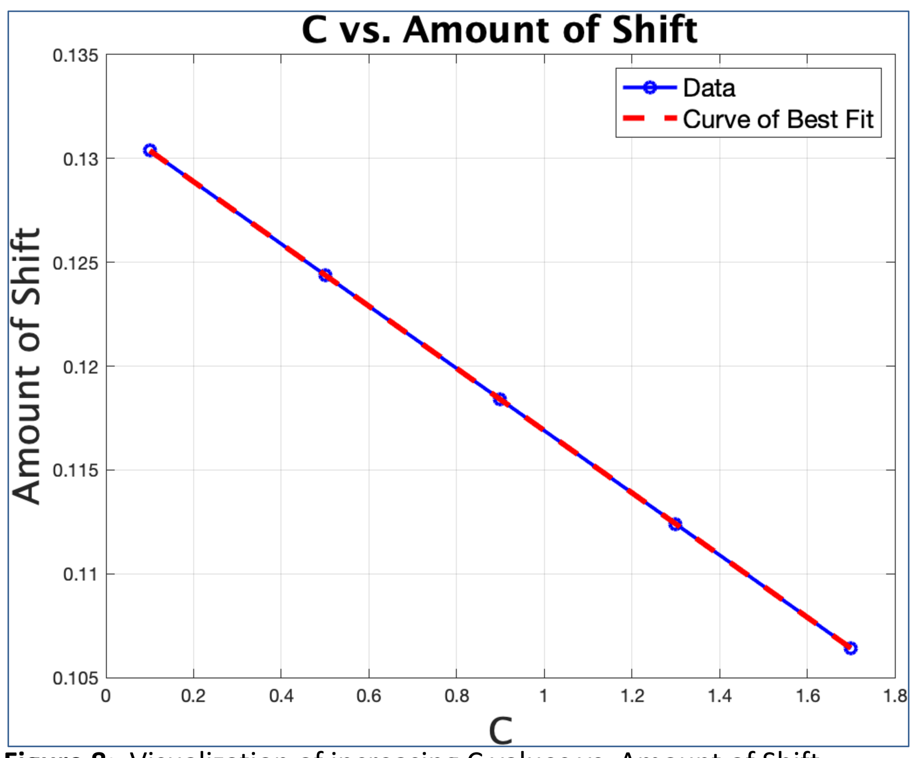

Figure 8: Visualization of increasing C values vs. Amount of Shift

Real-Time Neural Response

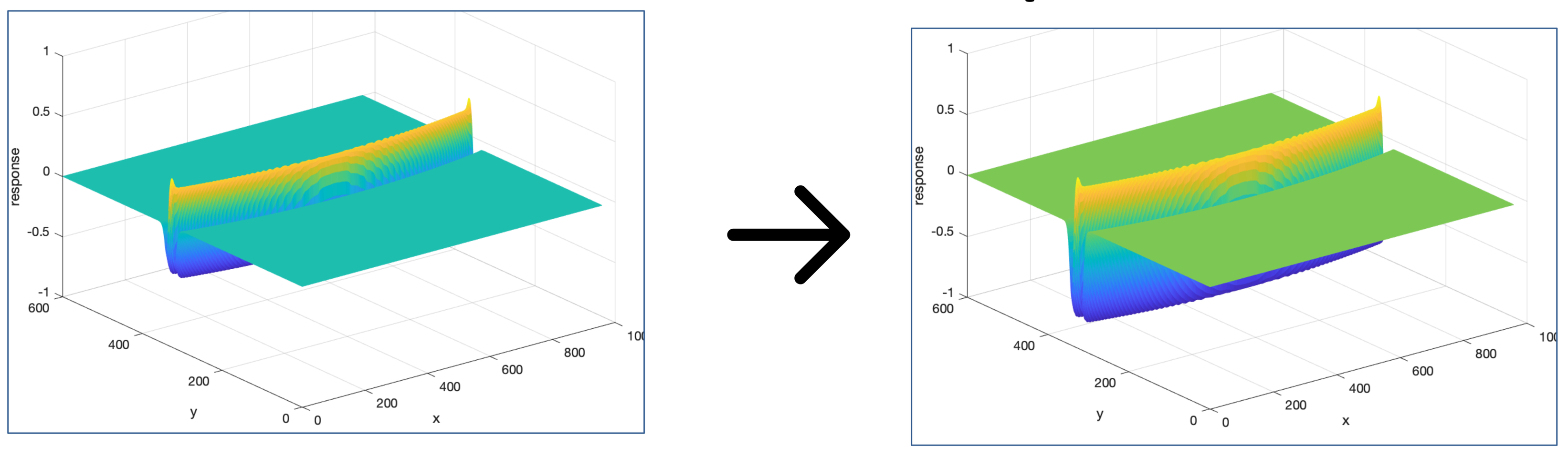

Figure 9: Simulating a curvature-responding neuron's real time response

Methods

Modeling Neural Processes

- MATLAB was used to take in an input curve and convolve it with the excitatory and inhibitory subfield of the LGN
- The Euler method was used to create a real-time neural response for the LGN — creating a 4D plot

Exploring Dynamic Activation (Excitation vs. Inhibition)

- The curvature inputs are used to investigate excitatory and inhibitory signals through the Dynamic Activation equation at equilibrium
- Variables A (decay rate of activation), B (upper limit of activation), and C (lower limit of activation) were manipulated to explore the amount of shift produced based on increasing values of each variable

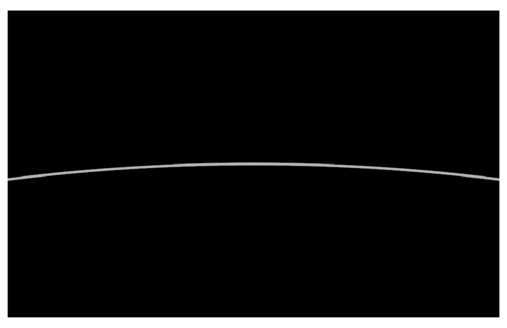

Figure 1: Example of input curve fed into LGN processing

$$x = \frac{BI_{exc} - CI_{inh}}{A + I_{exc} + I_{inh}}$$

Figure 2: Dynamic Activation Equation at Equilibrium

Discussion

LGN Processing Discussion

- The model successfully creates kernels for LGN processing that exists as a part of visual pathways
- Note that the inhibitory kernel is larger than the excitatory kernel due to the ON-center/OFF surround nature of the subset of LGN neurons. This allows for a more concentrated excitatory response and widespread inhibitory surround

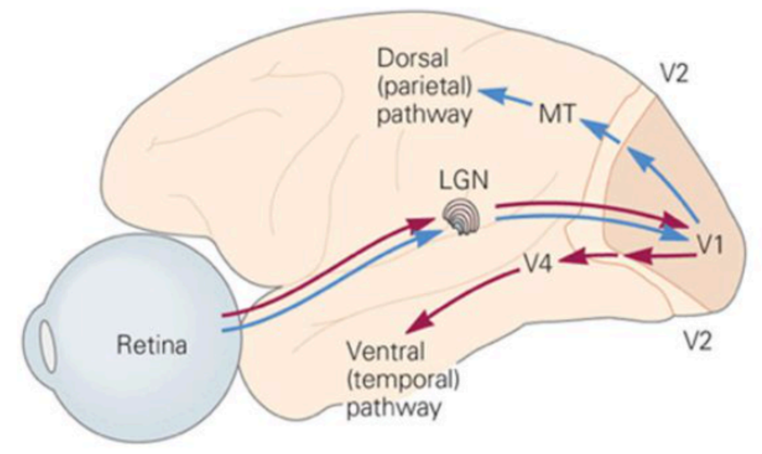

Figure 10: Visual pathway including LGN processing

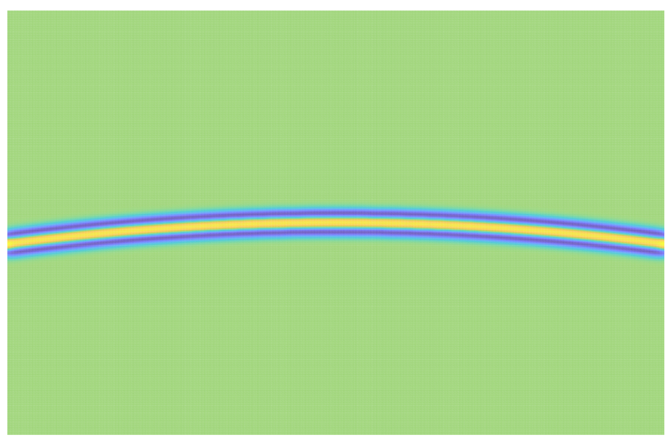

Figure 11: LGN response to input curve

Dynamic Activation Discussion

- Each curvature neuron is excited most by its corresponding curvature, while being inhibited every other curve.
- As inhibition increases within curvature processing, it becomes clear that excitation must increase as well in order to elicit a response.
- As values for A and C increased, the amount of shift decreased linearly; however, as values of B increased, the amount of shift increased quadratically.

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References

1. Xue, X., Robert, S., & Ungerleider, L. G. (2020). Curvature processing in human visual cortical areas. *NeuroImage*, *222*, 117295. https://doi.org/10.1016/j.neuroimage.2020.117295'
2. Amir, O., Biederman, I., & Hayworth, K. J. (2011). The neural basis for shape preferences. *Vision Research*, *51*(20), 2198–2206. https://doi.org/10.1016/j.visres.2011.08.015
3. Layton, O. W., Mingolla, E., & Yazdanbakhsh, A. (2014). Neural dynamics of feedforward and feedback processing in figure-ground segregation. *Frontiers in Psychology*, *5*, 972. https://doi.org/10.3389/fpsyg.2014.00972