A Lens Into Vision: Modeling the Stimuli-Driven Differential Responses of Lobula Columnar Cells in Drosophila

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Vision is a critical mode of perception that guides behavioral responses in many organisms. It is loosely grouped into two stages, sensing by photoreceptors and processing, further divided into levels ranging from low to high depending on the nature of the information being processed. Currently, while the functions of certain types of neurons are known for processing at a lower level, a comprehensive understanding of the exact mechanisms for processing at all levels is lacking. As testing using parameterized stimuli has proven to be insufficient for discovering which characteristics drive responses, the focus turns to the use of computational methods like deep learning to simulate neuronal activity. In this study, the Drosophila visual system was chosen for both its simpler anatomical structure and conserved mechanisms with higher organisms. To build interpretable models capable of simulating lobula columnar (LC) cells in the fruit fly brain, nineteen models, each corresponding to one LC cell type, were trained on a self-compiled dataset of over 300 dynamic stimuli paired with neuronal responses. An average correlation coefficient of 0.54 was found, indicating a moderate to strong correlation between predicted and ground truth responses. Upon plotting heatmaps of linear filter weights for each model, the mechanisms, scope, and level of processing behind each LC's computations could be interpreted. Collectively, these can help identify possible sequential interactions between different LC types. Further analysis also revealed these heatmaps' utility for identifying neuron types likely to be a part of the same functional group. By balancing complexity and interpretability, these models allow for more efficient investigations into the mechanisms behind visual processing.