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Computation of Visual Neurons in LGN–V1 Transmission

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Abstract—In the lateral geniculate nucleus (LGN), it is reported that mean firing rates and higher order statistics change with time while a drifting sinusoidal grating was presented. On the other hand, such characteristics cannot be observed in the primary visual cortex (V1). Focusing on such differences, we construct a minimal cortical model of LGN–V1 transmission. As a result, we show that highly precise spike timings are essential for information coding in the LGN, while noisy spikes are utilized in V1.

1. Introduction

In the visual system, there exist a pathway from the lateral geniculate nucleus (LGN) to the primary visual cortex (V1), so-called the optic radiations. Neurons in the LGN send visual information coming from the retina to the V1. In the LGN of Macaca fascicular, it is reported that the mean firing rate changes with time while a drifting sinusoidal grating was presented [1]. In addition, we reported that temporally changing spike train local irregularity could be observed from the neurons in the LGN [2]. These facts indicate that neurons in the LGN use two types of neural coding scheme: firing rate coding and temporal coding. However, it is unknown how such complicated information treated in the LGN can be processed in the V1 area. In this study, we show the spike train local irregularity statistics observed from the V1 while a drifting sinusoidal grating was presented. A possible information processing role in LGN–V1 transmission is then discussed.

2. Response onset and offset in visual neurons

We applied spike train analysis methods in Ref. [3] to the spike data recorded from the LGN and V1 [1]. The data we used are publicly available from the Neural Signal Archive ([4], http://www.neuralsignal.org). The recordings were obtained while a drifting sinusoidal grating was presented. From the results of temporally changing behavior of the spike train statistics observed from the LGN, irregularity of the spike train is high in the early stage, then gradually decreases, then finally increases again. These changes were independent of the mean firing rates. On the other hand, in V1 area, there was no significant change of the statistics independent of firing rates.

For reproducing characteristic behaviors of the statistics in V1, we construct a minimal spiking neuron model. By introducing large amplitude of noise for V1 neuronal input, characteristic V1 statistics can be observed. On the other hand, highly precise spike timings with much smaller values of noise are essential for reproducing characteristic statistics in the LGN.

3. Conclusion

In this paper, we used spike train analysis methods proposed in Ref. [3] to physiological spike data [4], and found different coding schemes between the LGN and V1. By introducing noisy LGN–V1 pathway, characteristic behaviors of the statistics in V1 can be reproduced. These results in the LGN and V1 may provide novel insights to neural codes in visual information processing.

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