LGN bursts enhance detection of specific stimulus features

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Abstract

During visual stimulation, neurons in the lateral geniculate nucleus (LGN) of the thalamus exhibit two distinct response modes, tonic and burst. There is mounting evidence that each mode serves a distinct function: burst firing signals the appearance of a salient stimulus (detection), while tonic firing relays detailed stimulus features (transmission). Recent studies comparing the responses of LGN cells to natural scene movies and white-noise have shown an increase in bursting during natural stimulation, and this increase has been linked to the statistical properties of natural scenes. However, while these studies suggest the importance of LGN bursts during natural vision, the precise functional role of the burst mechanism remains an open question. Here, we characterize the stimulus features that elicited tonic and burst responses in the LGN during natural stimulation and investigate the utility of the burst mechanism for dectecting these features.

To characterize the features that triggered tonic and burst responses during natural stimulation, we analyzed the responses of a population of cat LGN ON-center X cells to natural scene movies. The stimulus features that triggered tonic and burst responses were strikingly different. The average stimulus that preceded a burst, known as the burst-triggered average (BTA), started at the mean luminance value, gradually decreased from 200 to 100 ms before the burst, and rapidly returned to the mean luminance value from 100 to 50 ms before the burst. The average stimulus that preceded a tonic spike, known as the tonic-triggered average (TTA), started at the mean luminance value, rapidly increased from 100 to 50 ms before the burst, and gradually returned to the mean luminance value.

To investigate the utility of the burst response mode in detecting the appearance of these features, we simulated the LGN response with and without bursts, and compared the results using signal detection theory. To simulate the LGN responses, we used both a traditional integrate-and-fire (IF) model, as well as an IF model with an additional low-threshold, voltage dependent current for generating bursts, known as the integrate-and-fire-or-burst (IFB) model. The ability of the IFB model to signal the appearance of the BTA (alone and embedded in a background of noise) was far superior to that of the standard IF model, as indicated by area under the ROC curve, while the ability of both models to signal the appearance of the TTA were similar. These results demonstrate that the nonlinear amplification provided by the burst mechanism enhances the ability of an LGN neuron to detect specific stimulus features and suggest that bursts could be used as a reliable signal to direct the deployment of attentional resources to a behaviorally relevant area of the visual field.

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