

The Augmentation of Retinogeniculate Communication during Thalamic Burst Mode

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Retinal signals are transmitted to cortex via neurons in the lateral geniculate nucleus (LGN), where they are processed in burst or tonic response mode. Burst mode occurs when LGN neurons are sufficiently hyperpolarized for T-type Ca^{2+} channels to deinactivate, allowing them to open in response to depolarization, which can trigger a high-frequency sequence of Na^{+} -based spikes (i.e., burst). In contrast, T-type channels are inactivated during tonic mode and do not contribute to spiking. Although burst mode is commonly associated with sleep and the disruption of retinogeniculate communication, bursts can also be triggered by visual stimulation, thereby transforming the retinal signals relayed to the cortex. To determine how burst mode affects retinogeniculate communication, we made recordings from monosynaptically connected retinal ganglion cells and LGN neurons in male/female cats during visual stimulation. Our results reveal a robust augmentation of retinal signals within the LGN during burst mode. Specifically, retinal spikes were more effective and often triggered multiple LGN spikes during periods likely to have increased T-type Ca^{2+} channel activity. Consistent with the biophysical properties of T-type Ca^{2+} channels, analysis revealed that effect magnitude was correlated with the duration of the preceding thalamic interspike interval and occurred even in the absence of classically defined bursts. Importantly, the augmentation of geniculate responses to retinal input was not associated with a degradation of visual signals. Together, these results indicate a graded nature of response mode and suggest that, under certain conditions, bursts facilitate the transmission of visual information to the cortex by amplifying retinal signals.

Key words: cortex; LGN; retina; thalamus; vision

Significance Statement

The thalamus is the gateway for retinal information traveling to the cortex. The lateral geniculate nucleus, like all thalamic nuclei, has two classically defined categories of spikes—tonic and burst—that differ in their underlying cellular mechanisms. Here we compare retinogeniculate communication during burst and tonic response modes. Our results show that retinogeniculate communication is enhanced during burst mode and visually evoked thalamic bursts, thereby augmenting retinal signals transmitted to cortex. Further, our results demonstrate that the influence of burst mode on retinogeniculate communication is graded and can be measured even in the absence of classically defined thalamic bursts.

Introduction

The lateral geniculate nucleus (LGN) of the dorsal thalamus is the primary source of visual signals sent to primary visual cortex, receiving monosynaptic input from retinal ganglion cells (RGCs)

and projecting directly to cortical target neurons. Despite being labeled a relay nucleus, the LGN serves to transform retinal signals in several significant and dynamic ways (Dan et al., 1996; Usrey et al., 1998; Martinez et al., 2014; Fisher et al., 2017; Alitto et al., 2019), including changes in the temporal domain that accompany tonic and burst activity modes (for review, see Sherman and Guillery, 2009; Usrey and Alitto, 2015). During tonic mode, LGN neurons respond to excitatory input with regularly spaced action potentials, the rate of which is proportional to the strength of the stimulus (Llinás and Jahnsen, 1982; Huguenard and McCormick, 1992). By contrast, LGN spike trains during burst mode are irregular and include tight clusters of spikes known as “bursts,” and the firing rate becomes uncoupled from stimulus

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