

Retinal oscillations carry visual information to cortex

K. Koepsell¹, X. Wang², Y. Wei², Q. Wang², V. Vaingankar², J.A. Hirsch² and F.T. Sommer¹

¹University of California, Berkeley, ²University of Southern California

Neuroimaging with PET and MRI have shown that ongoing activity in the resting brain accounts for more than 90% of energy consumption in the brain[1]. The function of ongoing activity, which is often oscillatory, is one of the big mysteries in Neuroscience. Here we report the discovery of an information channel that is mediated by ongoing oscillations and can be used to transmit information from the eye to the brain. Specifically, retinal oscillations provide a previously unknown independent second channel of information using a form of multiplexing similar to methods used in technical communication systems: The two different channels are assigned to separate frequency bands of the spike train of single relay cells in the thalamic lateral nucleus. We were able to unmask this novel channel by combing experiment, model and theory. First, we used whole cell recording *in vivo* to gain direct access to the precise timing of both retinal inputs (EPSPs) and thalamic spikes during the presentation of natural movies. Second, we developed new methods to detect intracellular events and to quantify the information carried in spike timings with respect to ongoing activity. Third, we devised a model of the thalamic relay cell that reproduced the experimental findings.

Previously, we showed that much of the variance in responses of thalamic relay cells to repeated stimuli could be explained by intrinsic retinal oscillations that are not time-locked to the stimulus. Specifically, we found that spike latencies with respect to the stimulus were far more variable than spike timing with respect to retinal EPSPs, which showed millisecond fidelity. Here we explored how the stimulus and the intrinsic oscillations influence spike timing by building a multiplicative model of the relay cell. The model described spiking by a point process where the density is given by the product of two functions. One is the usual stimulus transfer function, i.e., the low-passed convolution between visual input and the receptive field. The second function represented the impact of intrinsic retinal oscillations; its periodicity and phase were determined from recent synaptic input. The degree to which thalamic activity phase-locked to the retinal oscillations was described by a von Mises distribution whose two parameters were tailored for each cell. The model was able to reproduce experimentally measured spiking statistics and information rates and thus revealed a multiplicative scheme for thalamic spike trains to generate dual channels for visual information to reach cortex.

It is likely that the two channels transmit different types of information downstream. Stimulus-locked coding is suited to provide information about local patterns that fall on individual receptive fields. By contrast, oscillation-based coding, which is produced by spatially distributed retinal networks, could provide information about global context. Thus, beginning at the sensory periphery, the code formed by neural spike trains can be parsed into parallel streams that communicate complementary information about local detail and the big picture. Recent experiments in frog support the prediction that oscillations convey such contextual information[2].

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References

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