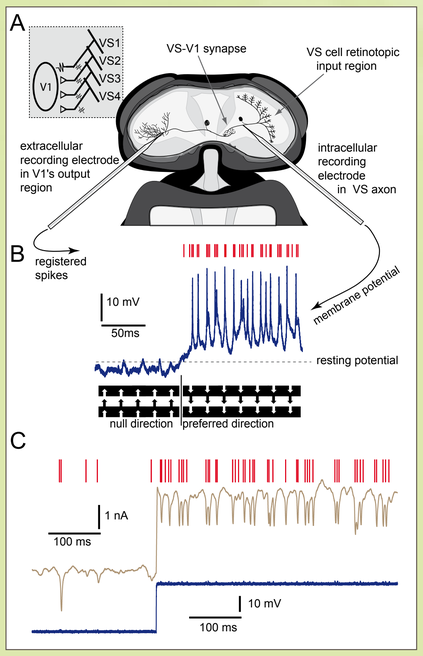
Universität Bielefeld

Ulrich Beckers, Martin Egelhaaf and Rafael Kurtz
Department of Neurobiology, Bielefeld University, 33501 Bielefeld, Germany
ubeckers1@uni-bielefeld.de

Impact of presynaptic voltage transients on postsynaptic spike timing at a graded synapse in the fly motion vision system

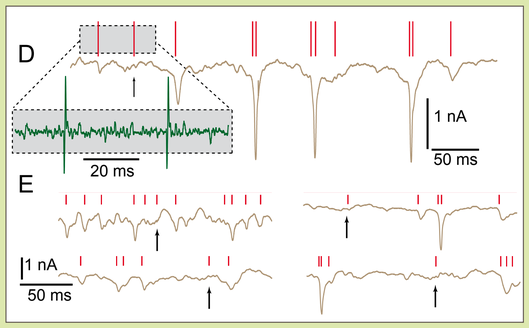
Introduction

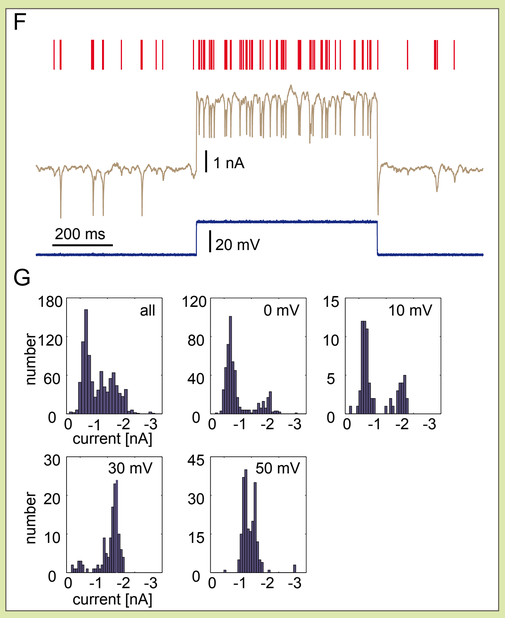
Information transfer between synaptically coupled neurons can be mediated by spikes, by graded signals, or by combination of both types of signals. We simultaneously recorded from identified visual motion sensitive cell pairs of the fly (A). The presynaptic VS cells convey both graded and spike signals (VS membrane potential: blue traces) to their common purely spiking postsynaptic target cell V1 (V1 spikes indicated as red dashes). The VS cells are electrically coupled among one another[1]. Synaptic transmission of graded signals from VS to V1 is linear over a broad signal range[2]. Postsynaptic spikes were elicited by voltage clamp (C) or injecting brief current pulses (H) into one VS cell. In this study we analyzed the time course of the holding current (C-G) to monitor the input received by the presynaptic cell and the correlation of V1 spike activity to single VS spikes (H-K). The role of fast signals for postsynaptic synchronization was studied by functionally removing one VS cell from the input ensemble (L-N).



Results

When a presynaptic VS cell is voltage clamped V1 spikes are accompanied by a brief hyperpolarizing current transients in the clamped VS cell (C). Some V1 spikes (3.1%) are not accompanied by a detectable current transient (D-E). The amplitudes of these transients are not uniform (F). Some VS2/3 cells showed a clear bimodal distribution of current transient amplitudes (G).

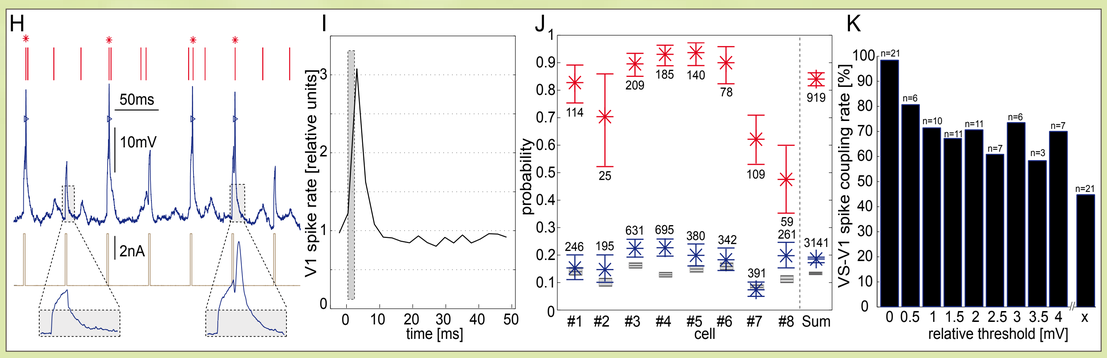




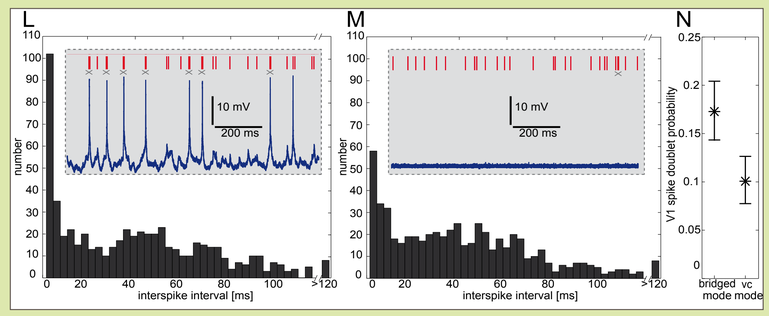
The occurence of 'failures' (V1 spikes not accompanied by a current transient in VS), the different amplitudes of the current transients, and in particular the bimodal distribution, speak against the assumption that the observed current transients result mainly from electrical coupling between VS and V1. We therefore propose that due to electrical coupling among the VS cells the current transients are caused by the occurrence of spikes in neighboring VS cells.

Results

To assess how the occurrence and timing of V1 spikes is affected by VS spikes we monitored V1 spiking activity when single VS spikes were elicited by brief current injections (H). V1 spikes were



tightly coupled to the injected current pulses in time (I). On occurence of a VS spike a V1 spike followed with much higher probability than when the current pulse remained subthreshold, i.e. when it failed to elicit a VS spike (J). The larger a VS spike is, the higher is the probability that a V1 spike is triggered (K).



Voltage clamping of one VS cell during rest (i.e. in the absence of visual motion) left the postsynaptic spike rate unaffected. However, the interspike interval distribution of V1 spikes was affected. While in the non-clamped situation (L) many doublet V1 spikes (marked by the X) occurred, the occurence of doublet V1 spikes was significantly reduced when one VS cell was voltage-clamped (M, N).

Conclusions

We conclude the spike rate of the postsynaptic V1-neuron to be controlled by both, graded voltage modulations and spikes of the presynapic VS cells. Whereas the graded presynaptic component regulates the postsynaptic spike rate to a large extent, the presynaptic spikes predominantly control the actual timing of postsynaptic spikes. Presynaptic spikes play a role for ensemble synchronization, as is evident from the decrease in the rate of postsynaptic spike doublets when one VS cell is prevented from spiking. Signal transmission from VS to V1 is largely mediated by chemical synapses, but an additional contribution from electrical coupling cannot be excluded and an eleclectrical coupling between VS1 and V1 has recently been shown[3].

Literature

1) Haag and Borst (2004) Neuronal mechanism underlying complex receptive field properties of motion-selective interneurons. Nat Neurosci 7:628-635
2) Beckers et. al. (2007) Synapses in the fly motion vision pathway: evidence for a broad range of signal amplitudes and dynamics. J Neurophysiol 97:2032-2041
3) Haag and Borst (2008): Electrical coupling of lobula plate tangential cells to a heterolateral motion-sensitive neuron in the fly. J Neurosci 28(53):14435–14442

Contribution to the 8th NWG Göttingen Meeting 2009