Spike-time response curves in interneurons of rat somatosensory cortex

Takashi Tateno[1] and Hugh P. C. Robinson[2]

[1] Osaka University and [2] University of the Cambridge

E-mail: t-tateno@bpe.es.osaka-u.ac.jp

Population oscillations in neural activity in the gamma (> 30 Hz) and beta (10-25 Hz) frequency ranges are found over wide areas of the cortex. Interneurons are believed to play a significant role in generating these synchronized oscillations through mutual synaptic and gap-junction interactions. Recently, in the somatosensory cortex, the details of neural connections formed by several types of GABAergic interneurons have become apparent. However, little is known about the mechanism of synchronized oscillation and how oscillations are maintained stably at the local network level. To obtain more insight into this from the viewpoint of nonlinear dynamical systems, we measure action-potential responses (spike-time response curves, SRCs) to a small or comparatively large current-pulse perturbation during periodic membrane-voltage oscillations of the beta or gamma frequency range, for three types of interneurons: non-pyramidal regular-spiking, low-threshold spiking, and fast-spiking (FS) cells. Although all the SRCs were biphasic with phase delay and advance regions separated by a discontinuity, their shapes and sensitivities to perturbation amplitude greatly depended on the cell type. For instance, SRCs of FS cells were less sensitive to perturbation amplitude, and showed much less spike delay than those of the other two cell-types. To quantitatively characterize the stability of coupled identical oscillators with the observed SRCs, we applied the phase-reduction method to oscillators with a weak chemical or electrical synaptic connection. Although the model is not applicable for strong synaptic connections, this work should help to elucidate the basic mechanism of synchronized oscillations in complex cortical networks.

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