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Spike timing – an incomplete description of neural code

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Starting with Hebb's investigations the time domain was an important apparatus to study neuronal activity. Increases or decreases in firing rate, precise spike timing sequences or particular spike time patterns were perceived as the only reliable measures of neural code. Despite considerable efforts and some success, the time approach does not seem to offer responses to several questions. What is the meaning of the time code in terms of behavior? Is the time domain consistent enough to measure complex neuronal activity?

One can answer these questions by measuring spike directivity in neurons as rats learned a T-maze procedural task. Based on in vivo recordings we recently demonstrated that spike time alone does not reflect the richness of neuronal activity [1-3]. Additionally, we showed that the electrical flow has directionality which becomes organized with behavioral learning.

We performed neuron simulations with plausible models of biophysically realistic neurons and demonstrated that mutual information between input signal and sodium flux is about two times that between input signal and output spikes during each spike within a millisecond-level time domain [2]. Consistent with this model and previous analyses we reveal that complex coding occurs in expert neurons and spike directivity analyses are able to reliably predict future animal actions [4]. This important feature in the spatio-temporal domain characterized by subtle changes in spike directivity at certain moments in time represents basic steps towards reading the neural code and marks a final requiem for spike timing era.

References

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