Information transfer between pyramidal neurons is optimized by synaptic background activity and short term plasticity

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Cortical neurons receive thousands of synapses whose excitatory postsynaptic potential (EPSP) amplitudes span an order of magnitude. Most synapses evoke EPSPs below 1mV; only a small fraction of EPSPs exceed 2mV. Such ‘strong’ connections predominantly occur between similarly-tuned neurons that tend to fire in synchrony, and are hypothesized to determine the postsynaptic neuron’s response[1]. In this study, we asked how the majority of inputs – having uncorrelated firing and ‘weak’ synapses – contribute to cortical computation.

We performed *in vitro* whole-cell recordings of layer 2/3 (L2/3) pyramids in mouse barrel cortex with extracellular single-fiber stimulation and recorded the distribution of EPSP amplitudes and corresponding short-term plasticity (STP). Using our results and pairwise correlation coefficients found in *in vivo* studies, we modeled a L2/3 pyramid whose presynaptic partners fired at an average 5Hz. We set 13% of input cells to have strong, depressing synapses and fire with temporal correlation. The majority of inputs were set to have weak synapses with weak STP and fire temporally uncorrelated spikes. We then quantified the ability of presynaptic cells to elicit spikes in the postsynaptic neuron by measuring the mutual information between each input spike train and the postsynaptic response.

Our simulations indicated that temporal correlations found *in vivo* maximized synaptic information transfer to 30bits/s. Notably, the presence of weak, temporally uncorrelated synapses increased information transfer of strong, correlated synapses by a factor of 2. STP contributed as a synaptic mechanism to stabilize firing by preventing strong, depressing synapses from driving the postsynaptic neuron into runway excitation, indicating that STP acts as a necessary filter to the presynaptic pattern of inputs.

Our results show how weak and strong synapses cooperate to shape the firing properties of cortical neurons, and highlight how neurons are intricately fine-tuned to use synaptic background activity and STP for efficient synaptic computation.

References

1. Cossell L, Iacaruso MF, Muir DR, Houlton R, Sader EN, Ko H, Hofer SB, Mrsic-Flogel TD. Functional organization fo excitatory synaptic strength in primary visual cortex. Nature. 19 Feb 2015; 518: 399-403.