from a macaque during free viewing of natural images. To measure the neurons' tuning to features of the stimulus in this context, we used Gabor-filter 'energy' models, modified such that the degree of stimulus tuning ('response gain') was a function of time since fixation onset. We also fit similar models to the LFP power in different frequency bands to describe the stimulus-evoked network activity. We found that, in addition to evoking a large, transient response in the spiking activity and LFP, saccades entrained ~10 Hz alpha oscillations in the LFP that persisted throughout the subsequent fixation. By transforming to time coordinates of alpha cycles, we found that these alpha oscillations modulated the response gain of V1 neurons, resulting in a temporal windowing of the stimulus processing following saccades. The stimulus tuning of gamma (35-60 Hz) power was similarly modulated by the alpha rhythm, and the gamma oscillations provided further temporal structure to the spiking activity through spike-phase coupling. These results show that during free viewing, alpha oscillations following saccades create a temporal windowing of V1 activity during fixations, and more generally suggest that stimulus-driven network dynamics may play an important role in shaping feedforward stimulus processing.

III-66. Theta and gamma activity during human episodic memory retrieval.

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The ability to successfully retrieve stored memories is a fundamental process in episodic memory, but the neural substrate mediating memory retrieval is largely unknown. To investigate this issue, we conducted an experiment in which 60 neurosurgical patients with implanted subdural electrodes participated in a delayed free recall task. The location and timing of neural processes that support memory retrieval were examined by calculating instantaneous power fluctuations in theta and gamma frequency bands. We found that memory retrieval is initially marked by an increase in theta activity in the lateral temporal cortex and medial temporal lobe, which lateralized to the right versus the left hemisphere. Increases in gamma power followed this theta activation and were especially prominent in the left hippocampus. Together, these data suggest that both theta and gamma activity play a central role in episodic memory retrieval and can be used to track memories with high-temporal precision leading up to the point in which they are spontaneously vocalized.

III-67. A recurrent neural network that produces EMG from rhythmic dynamics

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It remains an open question how the firing rates of neurons in motor cortex (M1) lead to the EMG activity that ultimately drives movement. Recently, (Churchland et al., 2012)[1] reported that neural responses in monkey M1 exhibit a prominent quasi-rhythmic pattern during reaching, even though the reaches themselves are not rhythmic. They argued that M1 could be understood as 'an engine of movement that uses lawful dynamics', i.e., that M1 could be viewed as a dynamical system. A major question posed by their work is finding a concise set of equations for a dynamical system that uses rhythmic patterns to drive EMG. We approached this problem by training a nonlinear recurrent neural network (RNN) (Sussillo and Abbott, 2009) to generate the recorded EMG during the same reach tasks used in [1]. We trained the RNN to simultaneously generate the EMG activity recorded from three muscles for 27 'conditions' (reach types). The network was provided with condition-specific static inputs as an initial condition, derived from the actual preparatory activity of recorded neurons. The RNN architecture consisted of a simulated M1 circuit, which provided input to three separate spinal cord circuits, one for each muscle. The model makes two main points. First, it is possible to produce realistic EMG activity using a network of this structure with the inputs provided. In particular, the input received during planning (derived from real neural data) provided a sufficiently detailed set of initial states to allow successful production of EMG for all 27 conditions. Second, the network naturally employs a solution that seems not unlike that used by the brain. This is true both on the surface level – simulated neurons appear very realistic, and on a mechanistic level, a large untuned component carries the neural state into a region of dynamics that produces strong oscillations.

III-68. Natural firing patterns reduce sensitivity of synaptic plasticity to spike-timing

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Synaptic plasticity is sensitive to both the rate and the timing of pre- and postsynaptic spikes. In experimental protocols used to induce plasticity, the imposed spike trains are regular and the relative timing between every pre- and postsynaptic spike is fixed. This is at odds with natural firing patterns observed in the cortex of intact animals, where cells fire irregularly and the timing between pre- and post-synaptic spikes varies. To investigate synaptic changes elicited by in vivo-like irregularly firing neurons at different rates and realistic correlations between pre- and post-synaptic spikes, we use numerical simulations and mathematical analysis of synaptic plasticity models. We concentrate on a calcium-based model (Graupner and Brunel 2012), and further consider a voltage-based model (Clopath et al. 2010) and a spike-timing based model (Pfister and Gerstner 2006). To allow for comparison, all models are fitted to plasticity results obtained in vitro (Sjoestroem et al. 2001). We show that standard stimulation protocols overestimate the influence of spike-timing on synaptic plasticity. Using a simple modification of regular spike-pair protocols, we allow for neurons to fire irregularly. Such irregular spike-pairs reduce the amplitude of potentiation and depression obtained by varying the time difference between pre- and postsynaptic spikes. This protocol allows us to quantify the relative effects of firing rate and timing in natural firing patterns, and to predict changes induced by an arbitrary correlation function between pre- and post-synaptic spikes. We show that spike correlations change synaptic plasticity at low firing rates in all models; whereas their influence becomes negligible at high firing rates for the calcium-based model but remains significant for the other two models. Our findings yield predictions for novel experiments and help bridge the gap between existing results on synaptic plasticity and plasticity occurring under natural conditions.

III-69. Local edge statistics provides significant information regarding occlusions in natural scenes

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This study investigated the statistical properties of edges found in natural scenes. We focused on the relative proportions and distribution of occlusions edges: edges due to the occlusion of one region of the image from another.