

Long-lasting neuronal desynchronization caused by coordinated reset neuromodulation

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A number of brain diseases, e.g. movement disorders such as Parkinsons disease, are characterized by abnormal neuronal synchronization. Within the last years permanent high-frequency (HF) deep brain stimulation became the standard therapy for medically refractory movement disorders. To overcome limitations of standard HF deep brain stimulation, we use a model based approach. To this end, we make mathematical models of affected neuronal target populations and use methods from statistical physics and nonlinear dynamics to develop mild and efficient control techniques. Along the lines of a top-down approach we test our control techniques in oscillator networks as well as neural networks. In particular, we specifically utilize dynamical self-organization principles and plasticity rules. In this way, we have developed coordinated reset (CR) stimulation, an effectively desynchronizing brain stimulation technique. The goal of CR stimulation is not only to counteract pathological synchronization on a fast time scale, but also to unlearn pathological synchrony by therapeutically reshaping neural networks. According to computational studies, CR works effectively no matter whether it is delivered directly to the neurons' somata or indirectly via excitatory or inhibitory synapses.

The CR theory, results from animal experiments as well as clinical applications will be presented. MPTP monkey and human data will be shown on electrical CR stimulation for the treatment of Parkinsons disease via chronically implanted depth electrodes. Furthermore, acoustic CR neuromodulation for the treatment of subjective tinnitus will be explained. Subjective tinnitus is an acoustic phantom phenomenon characterized by abnormal synchronization in the central auditory system. In a proof of concept study it was shown that acoustic CR neuromodulation significantly and effectively counteracts tinnitus symptoms as well as the underlying pathological neuronal synchronization processes. Furthermore, CR normalizes the pathologically altered interactions between different brain areas involved in the generation of tinnitus.