Dose-dependent effects of transcranial alternating current stimulation on spike timing in awake nonhuman primates

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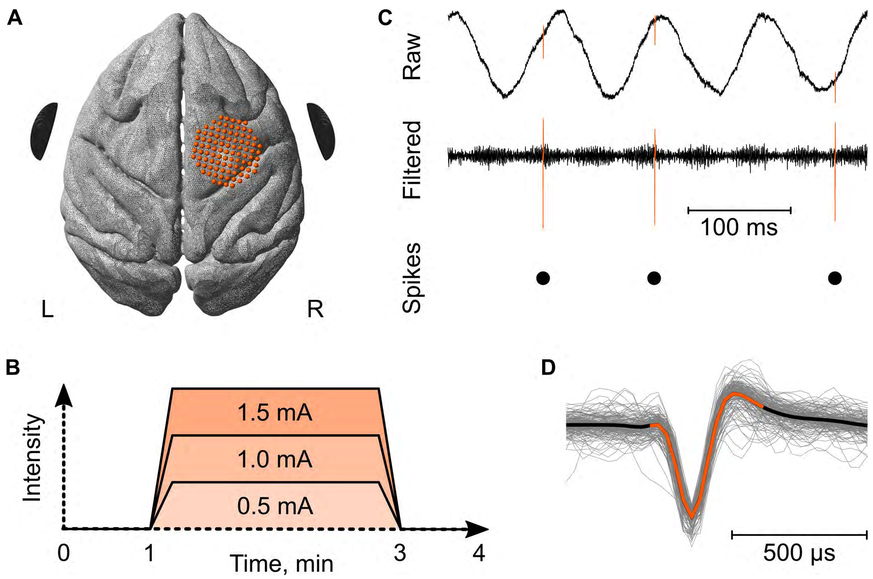
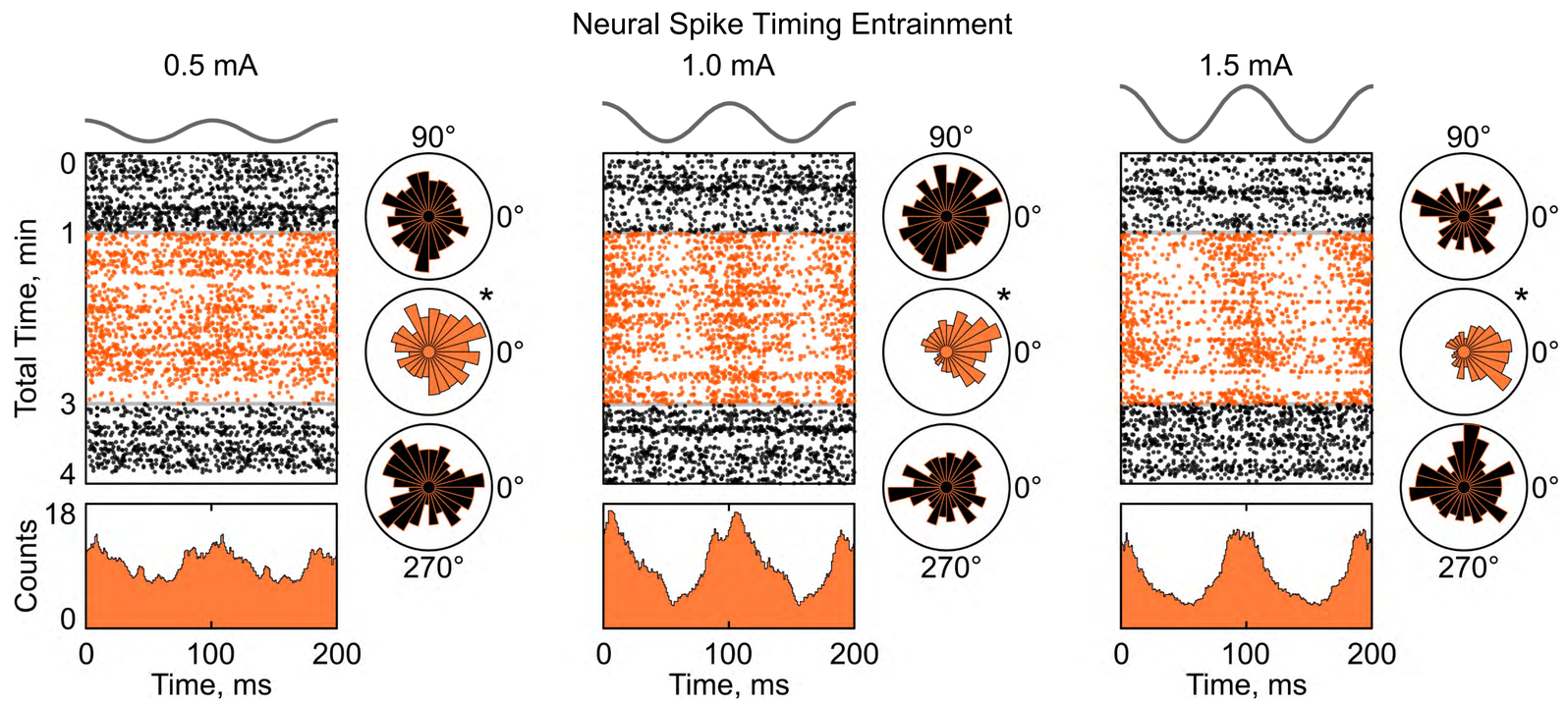
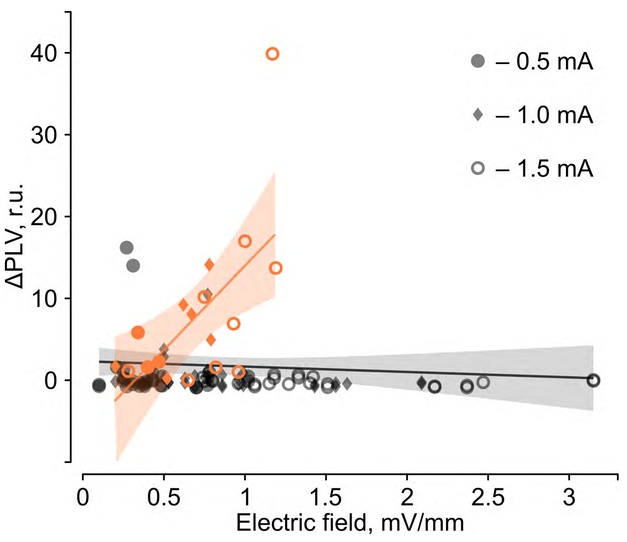
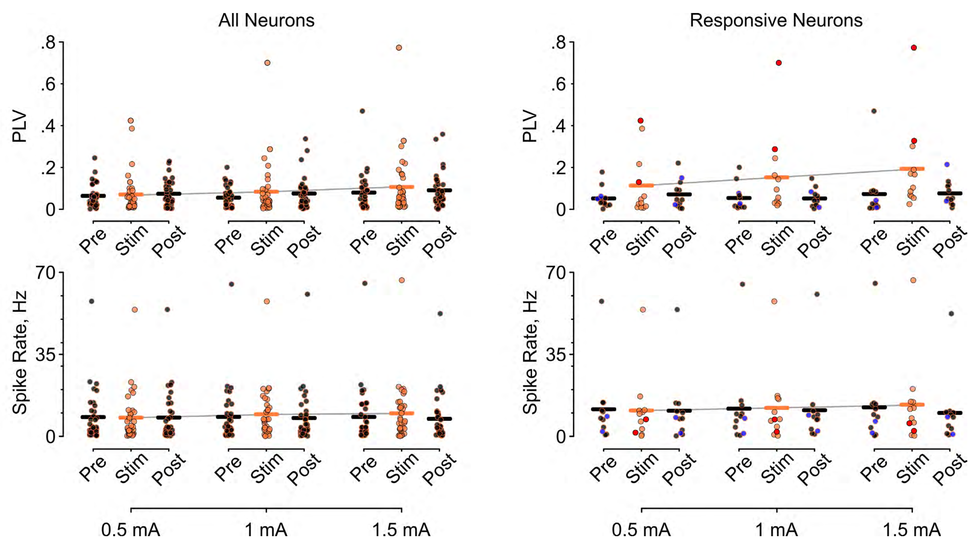
Transcranial alternating current stimulation (TACS) is an emerging neuromodulatory technique hypothesized to entrain neural spiking and brain oscillations to the phase and frequency of the applied oscillatory current. However, the conditions and dose regime in which these effects emerge remain debated. Here, we recorded single-unit activity in the neocortex in awake nonhuman primates during stimulation at 0.5, 1.0, or 1.5 mA.



We found that TACS-induced electric fields of approx. 0.4, 0.8, and 1.2 mV/mm entrained 8.9, 17.6, and 26.5% of all observed individual neurons (total n = 34), respectively. These entrainment effects occurred as phase-specific biasing of spike-timing to the peak (61% of cases), falling (22% of cases), or rising phase (17% of cases) of the applied alternating current (p-value < 0.01 in the Rayleigh test). The phase preference of the entrainment was neuron-specific; thus, the neurons demonstrated the same phase preferences at every stimulation dose they responded to. Besides the phase entrainment, we identified the second mechanism of TACS – the increase in spike burstiness, i.e., a shift toward shorter subsequent spike times during TACS compared to rest. These effects were not accompanied by the increase in the total number of spikes over time. To rule out possible peripheral effects, we conducted a control stimulation of the peripheral nervous system (a shoulder stimulation) at 1.0 mA. No effects on neural spiking were observed. Thus, we show direct and dose-dependent cellular level mechanisms of TACS in the awake primate brain. This work has great potential to inform future studies in humans.







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Find more: Johnson and Alekseichuk et al., Science Adv., 2020