What is the mechanical basis of traveling waves of neural activity observed in motor cortex?

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Neural recordings display a variety of phenomena that require modeling the nonlinear dynamics of neural networks to be understood. Here, we focus on beta frequency (~20Hz) oscillations that are observed in motor cortex during movement preparation [1]. In several experiments, local field potentials (LFPs) recorded on separate electrodes of a multi-electrode array have been observed to display transient oscillations with non-zero phase shifts. They organize into a variety of traveling waves types (planar, radial, rotating,..) [2,3,4]. Beta oscillations have been successfully modeled [5]. as arising from reciprocal interactions between randomly connected excitatory (E) pyramidal cells and local inhibitory interneurons (I). The synchronization properties of distant modules produced by distant-dependent excitatory coupling has also been studied [5,6]. What accounts for transient bursts of beta oscillations and the observation of spatial waves has, however, remained less clear. Here, we use a rate model (mean-field) description of the local neural activity that has been shown in previous works to provide an accurate population level description of more detailed network simulations based on coupled spiking neurons [6]. This offers the computational advantage that one can simulate and analyze large networks of local E-I modules with distance-dependent interactions and delays, matching those reported in previous experimental works. We study this model in a two-dimensional context. Stochastic local entries that vary on a long-time scale (200ms) are introduced to mimic inputs to the motor cortex from other neural areas. We compare our simulation results to electrophysiological datasets recorded in motor cortex of macaque monkey during an instructed delayed reach-to-grasp task [4]. We find that our model closely agrees with the recordings. It reproduces the observed power spectrum of the local field potential, produces a variety of traveling waves of speed and types similar to those seen in experiments. Our results suggest that both time-varying external entries and intrinsic network architecture shape the LFP dynamics of motor cortex.

References

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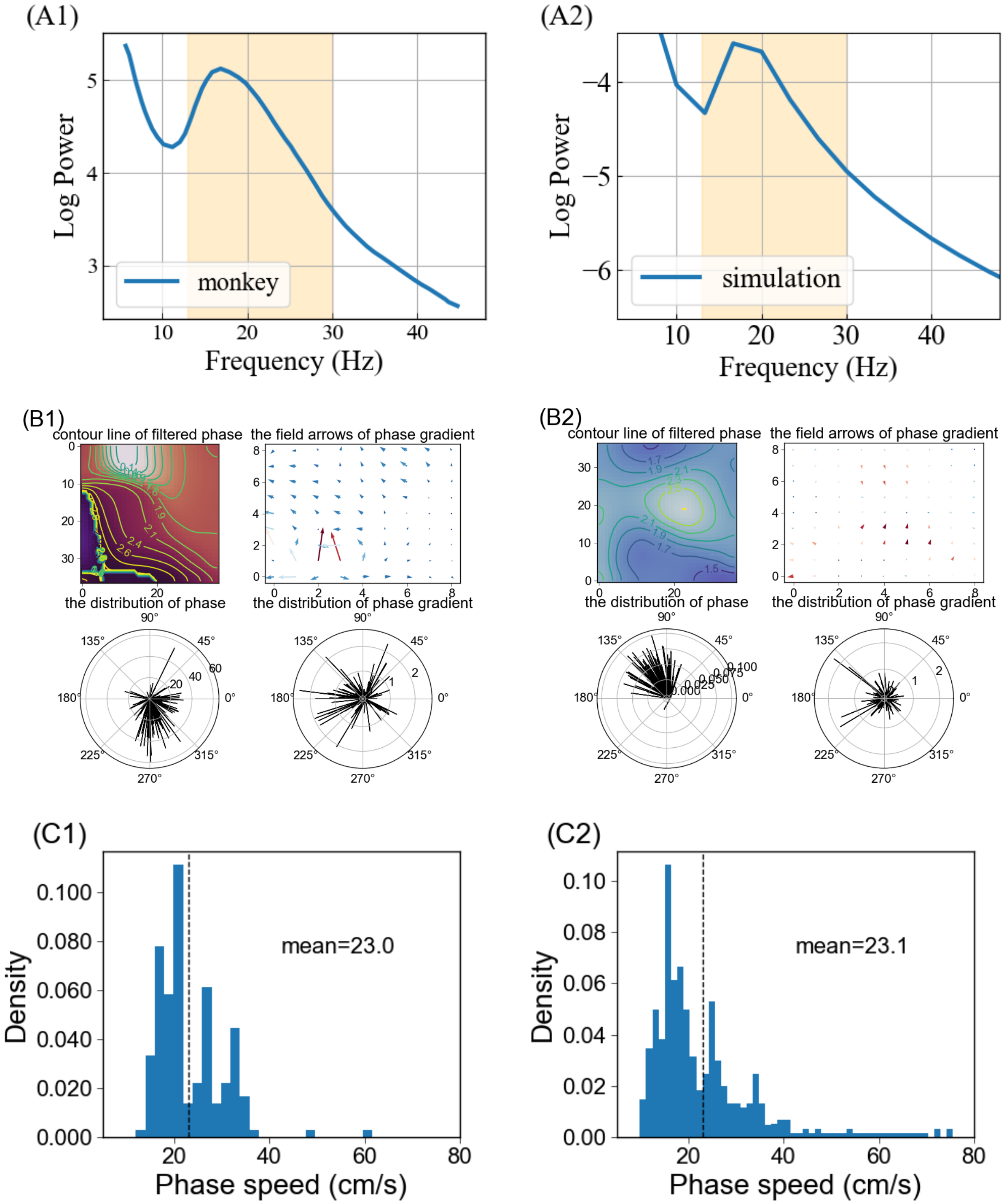

Figure 1. Comparison between experimental and simulation results. Left (A1-C1 experiment), (A2-C2 simulation) (A1) Power spectrum of the experimental LFP (A2) Power of total input current in the excitatory neuronal population (blue line) and a smoothed version (yellow). The two quantities measured in experiments and in simulations are approximately proportional (with an here undetermined scaling factor). (B) A snapshot of a propagating showing both the instantaneous oscillation phase and its spatial gradient as well as their distributions over different spatial locations in the snapshot. (C) The distribution of observed wave speeds distributions over a 1.8 s period for experiment (C1) and 5.0 s for simulation (C2).