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Respiratory rhythm and EEG oscillations in the olfactory system: a study using a biologically detailed model

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EEG oscillations are found in several structures of the olfactory system, like the olfactory epithelium (OE), olfactory bulb (OB) and pyriform cortex (PC). From the theoretical side a possible way to study mechanisms responsible for the origin of these oscillations is the construction of biologically detailed computational models, which can exhibit oscillatory neural activity and allow simulations of EEG measurements which can be compared with real data. In this work we present a large-scale biologically detailed model of the olfactory system consisting of models of OE, OB and PC and use it to study relationships between EEG oscillations in these three areas and the respiratory rhythm. The OE model contains 2500 olfactory sensory neuron models (OSNMs) distributed in a 50 × 50 square grid. The OB model has two cell layers, a 8 × 8 grid of mitral cell models and a 10 × 10 grid of granule cell models. The PC model has 96 pyramidal cell models distributed in a 16 × 6 grid and 225 interneuron models arranged in three layers with 75 model cells in each one of them. These three layers are called, respectively, multipolar cell layer, horizontal cell layer and globular cell layer. We developed a function that generates a receptor current in the OSNM based on a respiratory frequency and odor concentration. This receptor current is injected directly at the soma of an OSNM, simulating the effect of a stimulus. The responses of the OE, OB and PC were measured in terms of raster plots and simulated EEG records. In OE and OB, EEG records were made by single point electrodes placed at the centers of both the OE and OB models. In PC, the EEG was calculated as the average of the extracellular field potentials measured by a simulated grid of 8 × 5 point electrodes placed at the surface of the PC model. The results show that the slow components of the electrical oscillations produced in OB and PC are directly associated with the respiratory frequencies and odor concentrations at the receptor layer while the fast components are related with the intrinsic synaptic activity at each neural layer.

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