P062 A complete computational model to explore human sound localization

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Introduction

Animal ability to localize sounds in space is one of the most studied aspects of hearing. Sound source position is derived from interaural time difference (ITD), interaural level difference (ILD), and spectral cues. Despite decades of auditory neuroscience research, critical questions re main a bout the neural processes support ing human sound localization. Its understanding is particularly acute for cochlear implant users, whose devices often fail to provide precise spatial perception. Our aim is to address these interrogatives through the implementation of a comprehensive spiking neural network.

Methods

The model (depicted in Fig. 1) is composed of a peripheral section, from the sound to the spiking output of the cochlea, and a neural section, from the auditory nerve fibers to the superior olivary complex nuclei, developed using Brian-2Hears [1] and NEST [2] neural simulator respectively. The main inputs to the network are sounds used in in-vivo experiments in mammals, such as pure tones at different frequencies, clicks, and white noises. To evaluate how source position impacted the overall model activity, we provided stimuli of 1s duration from different spatial positions in the frontal azimuth plane, analyzing the corresponding spike distribution and overall firing rate of all the in-silico populations involved. Special attention was given to the activity of the lateral and medial superior olive s (LSO and MSO), two nuclei of the superior olivary complex considered to be the main players in the processing of ILDs and ITDs.

Results

The wide range of our model offered the possibility of facing various validation sites, comparing in-silico activity with different results obtained experimentally *in-vivo* or *in-vitro*. First, all neural populations showed a phase-locked spiking activity, with a refinement for higher-level populations fundamental for correct ITD processing [3]. The analysis of the overall population firing rate of LSO and MSO also showed physiological plausibility, with respectively an ipsilateral-increasing and a contralateral-increasing sigmoid-like behavior in response to shifting azimuth location[3, 4]. Finally, the reproduction of specific experimental setups focused on the MSO processing of ITDs showed coherent results in the effect of inhibitory input blockage [5] and in input delay manipulation on the overall MSO activity [6].

Discussion

The implemented computational model addresses some of the theories concerning the processing of sound and the computation of its location at the brainstem level in humans. We believe that our model could be a promising validation base for studying the effect of cochlear implant-generated artificial inputs for sound localization, shedding light on the different response of the involved auditory neurons with respect to a real sound stimulation.

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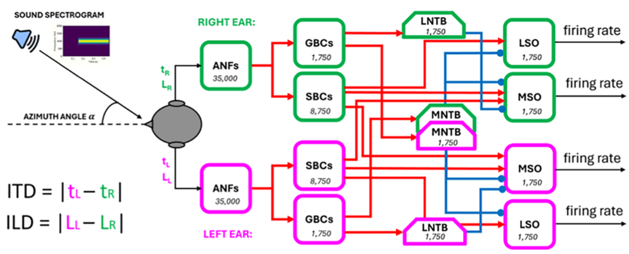

Figure 1: End-to-end spiking neural network

P063 Dichotomous Dynamics of Hippocampal and Lateral Septum Oscillations: State-Dependent Topology and Directional Causality During Sleep and Wakefulness

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Introduction

Sharp-wave ripples (SWRs) in the hippocampus (HPC) and high-frequency oscillations (HFOs) in the lateral septum (LS) play critical roles in memory consolidation and information routing to subcortical areas. However, the precise spatiotemporal dynamics and causal relationships between these oscillations remain poorly understood. Using multiple analytical approaches, we explored the coordination of HPC-SWR and LS-HFO oscillations during Non-Rapid Eye Movement (NREM) sleep and wakefulness, focusing on their topological features, causal relationships, and dimensional properties.

Methods

We analyzed publicly available LFP recordings from hippocampal subfields and the lateral septum in freely behaving rats [1]. To identify oscillations, we detected ripples following the methods described in [1]. To assess temporal coordination, we employed conditional probability analysis to quantify ripple co-occurrence between regions. To characterize oscillation structure, we applied Topological Data Analysis (TDA) using time-delay embedding (dimension = 3, delay = 2). To determine directional influences, we implemented Convergent Cross Mapping (CCM) for causality assessment [2]. To evaluate the dimensionality of neural activity, we utilized Principal Component Analysis (PCA) across individual channels, regions, and brain states [3].

Results

HPC ripples consistently preceded LS ripples, with the conditional probability of LS ripples given HPC-SWR, P(LS|HPC), higher than the probability of HPC-SWR given LS ripples, P(HPC|LS), especially during NREM sleep (Fig.1E). TDA revealed distinct topological structures: LS HFOs showed state-dependent complexity differences between sleep and awake, while HPC ripples maintained similar features across states (Fig.1D). Bidirectional causality analysis showed LS-HFOs influenced HPC-SWRs more than the reverse across both states, with a stronger relationship during NREM sleep (Fig.1C). Dimensionality analysis, examining SWR events across epochs/channels and applying PCA, highlighted the variability and complexity of SWRs in HPC compared to more uniform LS HFOs (Fig.1A,F).

Discussion

Our findings reveal a complex, bidirectional relationship between HPC and LS during ripple events, with stronger coupling during NREM sleep. The higher intrinsic dimensionality of HPC activity during SWRs reflects its role in complex memory processes, while the lower-dimensional LS activity suggests a streamlined relay function [1]. These results align with prior evidence showing LS neuron activation by hippocampal SWRs [1] and highlight state-dependent coordination between HPC and LS. State-dependent coordination changes suggest that during NREM sleep, the coordination supports memory consolidation, while during wakefulness, it facilitates spatial navigation and behavior.

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