Dynamic features of neural activity in primary auditory cortex captured by an integrate-and-fire network model for auditory streaming

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Summary. Past decades of auditory research have identified several acoustic features that influence perceptual organization of sound, in particular, the frequency of tones and the rate of presentation [1-2]. One class of stimuli that have been intensively studied are sequences of tones that alternate in frequency. They are typically presented in patterns of repeating doublets ABAB… or repeating triplets ABA_ABA_... where the symbol "−" stands for a gap of silence between triplets repeats. The duration of each tone or silence is typically tens to hundreds of milliseconds, and listeners hearing the sequence perceive either one auditory object ("stream integration") or two separate auditory objects ("stream segregation"). Animal studies have characterized single- and multi- unit neural activity and event-related local field potentials while systematically varying frequency separation between tones (DF) or the presentation rate (PR). They found that the B tone responses in doublets were differentially suppressed with increasing PR and that the B tones responses in triplets decreased with larger DF [1-2]. However, the neural mechanisms underlying these animal data have yet to be explained. In this study, we built an integrate-and-fire network model of the primary auditory cortex (AC) that accurately reproduced the experimental results from [1-2]. Then we extended the model to account for basic spectro-temporal features of electrocorticography (ECoG) recordings from the posteriomedial part of the Heschl's gyrus (HGPM; cortical area equivalent to the AC of monkeys), obtained from humans listening to sequences of triplets ABA_. Finally, we constructed a firing rate reduced model of the proposed integrate-and-fire network and analyzed its dynamics as function of parameters.

Results. A large network of voltage-dependent leaky integrate-and-fire neurons (3600 excitatory, 900 inhibitory) was constructed to simulate neural activity from layers 3/4 of AC during streaming of doublets and triplets. Parameters describing synaptic and membrane properties were based on experimental data from early studies of AC [3-4]. Network structure assumed spatially-dependent probability of connections and tonotopical organization. Subpopulations of neurons were tuned to different frequencies along the tonotopic map. In-silico recordings were performed during the presentation of long sequences of triplets and/or doublets. The network's output was derived with two types of measurements in mind: spiking activity of individual neurons and/or local populations of neurons, and local field potentials [5-6]. The network spiking neural activity reproduced reliably data reports from [1-2], including dependence of responses to the B tone in triplets ABA_ on stimulus parameter DF. Approximations of average evoked potentials (AEPs) from ECoG signals recorded at four depth contacts placed over human HGPM during auditory streaming of triplets were also obtained. The model accounted for features of HGPM activity such as short-latency large-amplitude responses and robust isomorphic representation of acoustic stimulus properties, including onsets and offsets of individual tones within the triplet.

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