BMC Neuroscience

Poster presentation

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Emergent pitch perception using short term plasticity

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from Eighteenth Annual Computational Neuroscience Meeting: CNS*2009
Berlin, Germany. 18–23 July 2009

Published: 13 July 2009

BMC Neuroscience 2009, **10**(Suppl 1):P197 doi:10.1186/1471-2202-10-S1-P197

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P197

Introduction

In pitch perception, the perceived frequency is the summation of the simple and complex sounds that form the complex harmonics. The phenomenon of the perceived missing fundamental frequency can be described as the frequency that is then perceived but is not actually present in the sound [1]. The mechanism in the cochlear nucleus that seems to be responsible is still unclear, however using simple phenomenologcial models we show that short-term plasticity is capable of solving this problem.

Short-term depression

It has been proposed that short-term depression may be involved in synaptic filtering and adaptation [2]. Using a modified Hindmarsh-Rose model [3], we demonstrate that a simple network of two mutually inhibitory neurons with short term depression, which are periodically driven with different frequencies, show the missing fundamental frequency as an emergent property. To achieve this, a novel post-synaptic potential model has been devised based on simplified Bessel equations. Short-term depression is then included using a mechanism described by Tsodyks et al. [4,5].

Emergent dynamic adaptation

The emerging frequency in the two-neuron model is the summation of the two input frequencies based on the principle of the least common multiple of the periods. The model can be extended to the least common multiple of three or more input frequencies without any apparent constraints, allowing the readily summation of many periodic signals. This demonstrates that dynamic adaptation made possible by the short-term depression is very effective at filtering and signal addition. The described mechanism is relatively insensitive to noise and wholly insensitive to phase shifts. Introducing arbitrary differences in phase in the input periods has no effect on the correctly emerging frequency. The summation of the input frequencies also allows other interesting phenomena such as the multiplexing of completely different signals at alternating timeframes.

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