A neural network model describing simultaneous stimuli properties selection and their subsequent composition in the hippocampus

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ABSTRACT

We propose a mathematical model for the simultaneous processing of several stimuli through their decomposition, filtering and extraction of their significant characteristics and their subsequent integration that take place in the hippocampus. The model process incoming signals of different sensory modalities and we provide an estimate of the minimum number of neurons needed to relaibly process such stimuli The model results are compatible with available experimental data.

***Keywords* - information coding, signal processing, oscillations, sensor fusion, neural activity, hippocampus**

SUMMARY

Recent experimental results show that external stimuli of different sensory modalities enter the hippocampus where they are processed and merged together [1,2]. Experimental data suggest that relatively slow oscillations of the neural membrane are involved in such processes [2]. However the underying mechanisms by which the hippocampus performs such fusion of information of different sensory modalities is still to be elucidated.

In the present communication we propose a neural network model that, based on experimental evidences [3-5], is composed by three coupled neuronal groups of oscillating neurons, with different functional properties that are capable to decode and select the valuable information (most significant characteristics) from different input signals and to produce an output response that consists of an interplay of the selected characteristics.

The neuronal groups are organized in two hierarchical levels. The first of them is responsible for signal decomposition and filtering of incoming stimuli and consists of a chain of oscillatory neurons that supply their spiking trains as an input for the second level. The second level performs the product, in a functional space, of the signals and is able to combine and integrate incoming information from different sensory pathways. This way the complete system convolves incoming signals of different sensory modalities, thus providing a mean to realize different representations of the fundamental components of complex stimuli.

To simulate individual neurons the Hodgkin-Huxley formalism is considered. We make use of a single-compartment model with homogeneous channel densities of leakage, Na^+, K^+, low-threshold Ca^{++} active channels [6]. Depending on the maximal conductancies the model may generate spike trains, low frequency subthreshold oscillations or be at rest.

We show that our network is plausible and its first level can rapidly and robustly decompose real signals from the incoming stimuli into their basic oscillatory components. Each component, based on a predetermined (or modulated by the higher levels of the brain) threshold is filtered, allowing a demasking of possibly small but vital information content to be performed. We check the robustness of the model to noise and evaluate the sensitivity to significantly different external stimuli. Then we study how the second level collects the data elaborated at the first stage and generates a product that finally could be furthermore treated. Besides, we estimate the minimum number of neurons that is needed for the described signal processing. The results of the model are compatible with experimental data from the hippocampus.

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