Early Information Processing in the Vertebrate Olfactory System

A Computational Study

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Abstract

The olfactory system is believed to be the oldest sensory system. It developed to detect and analyse chemical information in the form of odours, and its organisation follows the same principles in almost all living animals - insects as well as mammals. Likely, the similarities are due to parallel evolution - the same type of organisation has arisen more than once. Therefore, the olfactory system is often assumed to be close to optimally designed for its tasks. Paradoxically, the workings of the olfactory system are not yet well known, although several milestone discoveries have been made during the last decades. The most well-known is probably the discovery of the olfactory receptor gene family, announced in 1991 by Linda Buck and Richard Axel. For this and subsequent work, they were awarded a Nobel Prize Award in 2004. This achievement has been of immense value for both experimentalists and theorists, and forms the basis of the current understanding of olfaction. The olfactory system has long been a focus for scientific interest, both experimental and theoretical. Ever since the field of computational neuroscience was founded, the functions of the olfactory system have been investigated through computational modelling. In this thesis, I present the basis of a biologically realistic model of the olfactory system. Our goal is to be able to represent the whole olfactory system. We are not there yet, but we have some of the necessary building blocks; a model of the input from the olfactory receptor neuron population and a model of the olfactory bulb. Taking into account the reported variability of geometrical, electrical and receptor-dependent neuronal characteristics, we have been able to model the frequency response of a population of olfactory receptor neurons. By constructing several olfactory bulb models of different size, we have shown that the size of the bulb network has an impact on its ability to process noisy information. We have also, through biochemical modelling, investigated the behaviour of the enzyme CaMKII which is known to be critical for early olfactory adaptation (suppression of constant odour stimuli).

Key Words
olfaction, olfactory system, olfactory bulb, synchronisation, CaMKII, mathematical modelling