R.J. Smith, G. Leng and D. Willshaw
University of Edinburgh
Institute of Adaptive Neural Computation.
smithrj@anc.ed.ac.uk

Modelling the firing patterns of Mitral cells in the Olfactory Bulb.

Abstract

Mitral cells, the main output cells of the olfactory bulb, have been shown to fire in phasic bursts. Each burst comprises of a high frequency and a low frequency component. In vivo experiments on female sprague dawley rats verified these observations. Further experiments have shown that both dendritic stimulation and the addition of biccuculine have a decided effect on the firing pattern of the cells. We have now produced a model which is able to mimic the firing behaviour of these cells.

Mitral cells and their interactions

Mitral cells are the main output cells of the olfactory bulb. They receive their main input from a single olfactory nerve cell to their primary dendrite (Mori et al 1983) . They send information along their axon out to the piriform cortex and other surrounding structures (De Olmos et al 1978). Mitral cells do not form actual connections with other mitral cells. Instead they form, with their secondary dendrites, dendrodendritic connections with some local inhibitory cells called granule cells (Pinching and Powell 1971). A mitral cell releases glutamate from its dendrites (Wellis and Kauer 1994) which excites the granule cells who in their turn release GABA from their dendrites which inhibits any mitral cell they are in contact with (Shepherd 1972). Mitral cells are also capable of exciting themselves still furthur since they they have gutamate receptors on their dendrites (Aroniadou-Anderjaska et al 1999).

Experiments performed

Some firing patterns had been previously observed in mitral cells that were unverified in any papers. Thus our first aim in performing these experiments was to obtain some baseline recordings of mitral cells firing over a long period of time. The cells were verified as mitral cells by their postions in the bulb (either 1.5 or 3mm from the surface of the brain in the mitral cell layer), the fact that there was a clear evoked potential by each spike and the fact that the spike could be blocked by performing the collision test.

The animals used were female sprague dawley rats. They were kept under deep urethane (1.5ml 1.25kg/ml ip) anaesthesia and held in a stereotaxic frame. A stimulating electrode was placed in the Lateral Olfactory Tract (LOT) and a glass recording electrode was lowered on a micromanipulator into the olfactory bulb.

Once a mitral cell was found one of three protocols was applied to it. 1) the cell was left to run and a baseline was recorded, 2) biccucline (a GABA A antagonist) was added to the preparation, or 3) the area of the bulb surrounding the cell being recorded from was subjected to an electric pulse which would stimulate the dendrites of that cell.

The theory behind these experiments was that the high frequency componant of the firing observed in the baseline recordings was caused by a change in the site of action potential initiation from the soma to the dendrites (Shen et al 1999). Thus we changed the level of excitation possible in the dendrites to see whether this would affect the level of high frequency firing.

Results

The mitral cells showed very clearly the high frequency burst firing that we had been hoping to observe. Adding the biccuculine caused a clear increse in the high frquency componant of the firing pattern whilst the dendritic stimulation caused a sharp decrease in the high frequency firing. Neither protocol seemed to affect the timing of the bursts of firing.

The Model

The model is in Neuron and is based on an already existing model by Davison et al. which is turn is a reduction of Bhalla and Bowers model of a mitral cell from 1993. We have adapted the model so that it shows the phasic firing pattern observed in mitral cells in vivo. The effects of adding dendritic stimulation or biccuculine will be modelled by varying the excitability of the secondary dendritic compartment.

Conclusions

Whilst the experimental data does point towards a shift in the site of action potential initiation being the cause of the high frequency firing. There are many other explanations for the effects we have observed. Using a model of a mitral cell that can exactly model the baseline firing pattern we hope to be able to cause it to show the changes in firing frequency and thus provide more evidenceto support our theory that the high frequency firing in mitral cells is caussed by a shift in the site of action potential initiation from the soma to the dendrites.

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