Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Neurocomputing 65–66 (2005) 365–370
NEUROCOMPUTING
www.elsevier.com/locate/neucom

The effect of correlations in the background activity on the information transmission properties of neural populations ☆

Thomas Hoch*, Gregor Wenning, Klaus Obermayer

Department of Electrical Engineering and Computer Science, TU Berlin, Franklinstr. 28/29, 10587 Berlin, Germany

Available online 15 December 2004

Abstract

Recently, the information transmission properties of populations of neurons with independent noise inputs were examined and it was shown that noise can improve the transmission of sub-threshold signals. Information transmission is maximized at a certain noise level which, in general, depends on the population size. In the central nervous system of higher animals, however, the noise is likely to be correlated. In this paper we therefore investigate the effect of correlations between neurons on the information transmission properties of populations of neurons. We show that correlations in the noise inputs of neurons not only decrease information transmission but also immediately reduce the optimal population noise level to that of the single neuron. Hence, information about the population size does not need to be made available to the single neuron and therefore local adaptation rules as suggested in (Phys. Rev. Lett. 90 (2003) 120602) suffice.

Keywords: Stochastic resonance; Population coding; Local adaptation

☆ Supported by the DFG (SFB 618).
*Corresponding author.
E-mail addresses: hoch@cs.tu-berlin.de (T. Hoch), grewe@cs.tu-berlin.de (G. Wenning), oby@cs.tu-berlin.de (K. Obermayer).

0925-2312/$ - see front matter
doi:10.1016/j.neucom.2004.10.030

1. Introduction

It is well established that background activity can influence the information transmission properties of cortical neurons [2] as, for example, in a stochastic resonance setting [6]. The term *stochastic resonance* is used for the phenomenon, that in a nonlinear dynamical system noise can improve the information transmission to a certain fraction (see [3] for a review), and has been extensively studied in the context of single neurons [7]. However, in the central nervous system of higher animals single neurons rarely matter, and information is likely to be coded by populations of cells. In a recent study we have shown, that the optimal noise level of a population of neurons with mutually independent noise inputs depends on the population size [5]. If the dependency on the size is strong, a single neuron would need to process the information about the population size in order to establish optimal information transmission. If the dependency is weak, the neuron could instead use local quantities to calculate the proper noise level as suggested in [9]. In this paper we show that if correlations between neurons are considered, the optimal noise level of the population immediately reduces to that of the single neuron, which means that optimal information transmission can be achieved by a simple adaptation principle, for which only local information is needed. The assumption of correlated noise between neurons is reasonable from a biological point of view, because nearby neurons share a certain fraction of their input [4].

This paper is organized as follows. First we introduce our model which consists of a population of leaky integrate-and-fire neurons and we briefly describe how information transmission through the population is estimated. In Section 3 we present the numerical results and we show, how correlations in the background activity alter the information transmission properties of the neural population. Section 4, finally, concludes with a short discussion.

2. The model

2.1. The neural population

We consider a population of N leaky integrate-and-fire neurons as displayed in Fig. 1. The total input to each neuron i is the sum of the input signal I_{stim} and the individual correlated noise input $\mathrm{d}W(t)/\mathrm{d}t$. The entire output of the population is generated by summing over all individual outputs Y_i (called pooling in neurophysiological terminology) in every time step Δt.

The membrane potential V of the leaky integrate-and-fire neuron changes in time according to the following differential equation:

$$C_m \frac{\mathrm{d}V(t)}{\mathrm{d}t} = -g_{\mathrm{L}}(V(t) - E_{\mathrm{L}}) + I_{\mathrm{stim}}(t) + \sigma \frac{\mathrm{d}W_i(t)}{\mathrm{d}t}, \tag{1}$$

where $C_m = 0.5\,\mathrm{nF}$ is the membrane capacitance, $g_{\mathrm{L}} = 25\,\mathrm{nS}$ the leak conductance of the membrane, $E_{\mathrm{L}} = -74\,\mathrm{mV}$ the reversal potential, I_{bias} a constant bias current,