Determination of responses to stimuli by the role of signal-triggering neurons in the network

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***Abstract*—Visual stimulus discrimination ability of the brain means that somehow neuronal reaction has to differ concerning stimuli. We were interested in how we may find a nd describe the variation of neuronal response. We also wanted to pinpoint the structure of the neural network and functional interaction between its nodes. As a result, we propose a method for the characterization of neuronal response state to stimuli.**

***Index Terms*—synchronization, SPIKE-order, inferotemporal area, neurons**

I. Introduction

The motivation of the further methods was our need to analyze experimental recordings from the inferotemporal area of the brain. This area is known as the object-selective and face-selective area [1]. The experimental data contained the time-dependent electrophysiological activity of neurons of a 6-year-old monkey. The set of visual stimuli contained pictures of eight categories of objects. Monkey looked at these objects. Researchers picked the part of the time when the monkey's attention was focused. A detailed description of the experimental approach is in [2].

II. Synchronization, the order of spikes and leader-follower relations

Kreuz et al. [3,4] presented the method for measuring the value of synchronization of two neurons and for indicating the order of spikes from them. During synchronization, the neuron's role in a pair is rated as a leader if spike from it happened before the spike from the other neuron. The second one is, respectively, a follower. This method allowed us to make pairwise matrices. Each element from the matrix indicates an order of spikes. A positive value of the element means that neuron from the line is the leader to a neuron from the column and vise versa.

III. Sorting signal directions

The spike order matrix itself does not show a distinctive structure. Sorting may reveal spots on matrices that generalize relations between some pairs of neurons. We built a directional matrix for 19 neurons that stayed stable and continued to lead or follow for two days. During the sorting, pairs moved the way to maximize the sum of the upper right tridiagonal part of the matrix. The sorting applied an annealing simulation algorithm to permutate pairs optimally. The initial temperature was maximal matrix's value, and the final temperature was 1E-5, the cooling factor was 0.999999. At the end of sorting, the top leader neuron is on in the first line, and the top follower is on the last one. We performed this operation for each category of stimuli. The results are on the figure.

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IV. Hub neurons, divergency and convergency

In the results (Fig. 1 and Fig. 2), we noticed two types of hub neurons acting inside two schemes - convergence and divergence. In the case of convergency, multiple neurons are standing as leaders. If the sorted matrix has a column with positive values, there is a convergence happened. Each neuron on Y-axis is a source of synchronization for the neuron, which belongs to the column. The majority of sorted matrix except 'hiding' and 'mating' similarly have convergent hub neuron 26_1. By the naked eye, we may see a similar character of 'grooming' and 'baby-monkey' matrices. The divergent spreading of the signal is going from one source of synchronization to the followers. On a matrix, this kind of behavior would look like an easily allocatable line with positive values. Similarly, each neuron on X-axis is a source for the neuron from the line. Divergent hub neuron 22_2 is a synchro-source for ten neurons only at the 'hiding' matrix.

V. Summary

Sorting the order of spikes gives us the capability to discriminate states of the network, and also extract and characterize divergent and convergent hub-neurons. This approach may be implemented not only for the data from the visual inferotemporal area but also in the case of other stimuli-dependent or time-dependent studies.

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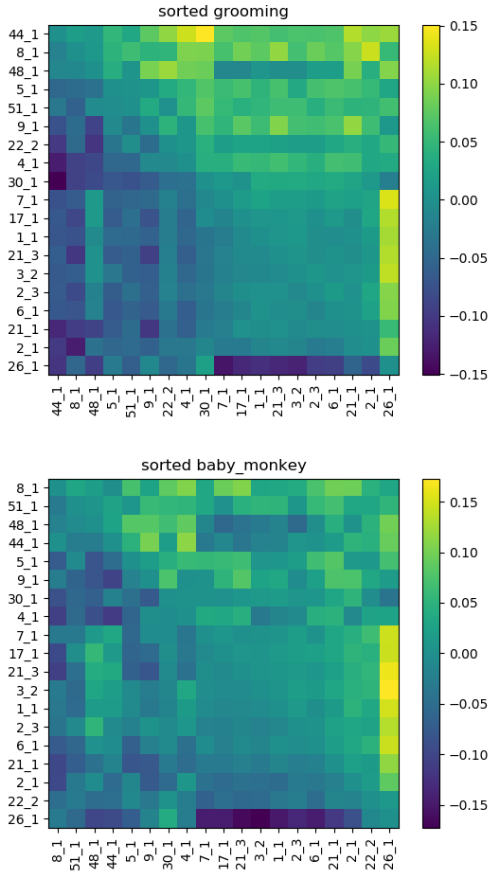

Fig. 1. Sorted pairwise matrices from 'grooming' and 'baby-monkey' category recordings. They similarly have neurons with convergent propagation of the signal to neuron 26_1.

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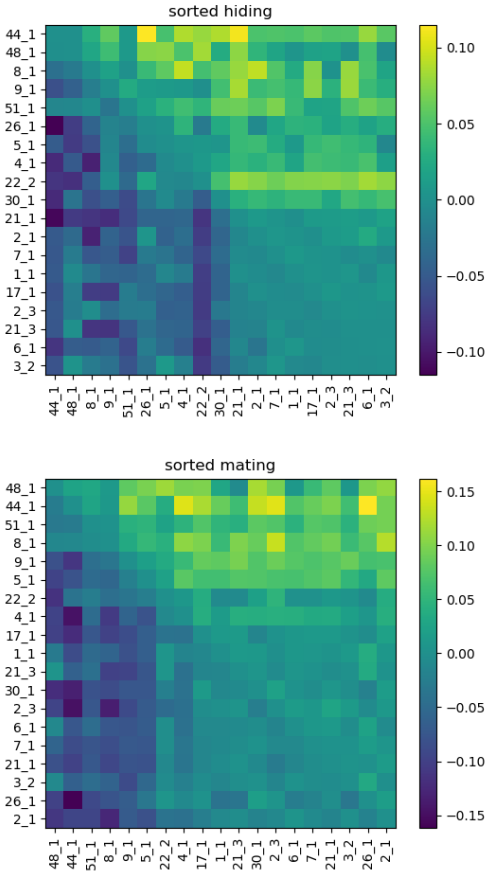

Fig. 2. Sorted pairwise matrices from 'hiding animals' and 'mating' category recordings. In the case of 'hiding', divergent propagation of the signal is going from neuron 22_2 to ten others.