Population dynamics during timing behavior in the rat prefrontal cortex

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Survival depends on being in the right place at the right time. Animals are able to keep track of elapsed time from the occurrence of behaviorally relevant events, and to act at the appropriate moment in order to, e.g., obtain a reward, or avoid a punishment (see e.g., [1]). As with any timing device, the neuronal signals used by the brain to read out elapsed time must change during the relevant interval, and must be reliable, so that whenever the amount of elapsed time since a relevant event is the same, their state should also be approximately the same. In this way time could be inferred from the current activity of the appropriate neuronal population. This scheme, however, poses a challenge for such a signal to be instantiated in the spiking activity of cortical neurons, since neurons are usually quite unreliable. When examining the responses of cortical neurons during a behavioral task across repeated trials, it is usually found that the variance in the spike-count is approximately proportional, or even higher, than the mean (see e.g., [2]).

In order to investigate this issue we recorded the simultaneous activity of neuronal ensembles from the medial prefrontal cortex of rats performing a timing task that requires them to make a single, temporally precise response, a few seconds after a sensory cue. We found that a substantial fraction of the cells we recorded are unusually reliable, with variance-to-mean spike count ratios as low as 0.3 in time windows of a few hundred milliseconds. This reliability is present despite relatively low firing rates on the order of 10 Hz. The reliability we observe is not the product of precise spike timing across trials, but rather of rhythmic, or regular, spiking. These cells show wide troughs in their auto-correlograms and different measures of inter-spike interval (ISI) variability (designed to take into account slow modulations in firing rate) reveal coefficients of variation significantly smaller than one.

A majority of cells in our current data-set are more faithfully locked to the animal's motor response (the time of which varies from trial to trial) than to time *per se*, so that time discrimination from this neuronal population is not possible throughout the trial. Discrimination is, however, possible on the few seconds *before* the motor response, with an accuracy on the order of one second. By generating artificial Poisson data, we directly assess the relevance of the spiking statistics of the recorded cells regarding time discrimination.

This research might contribute to the establishing of a quantitative framework for the understanding of the neurophysiological basis of self-timed behavior.

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References

[1] Time, rate, and conditioning. C.R. Gallistel and J. Gibbon, *Psychol. Rev.* 107(2):289-344, April 2000.

[2] The variable discharge of cortical neurons: implications for connectivity, computation and information coding. M.N. Shadlen and W.T. Newsome, *J. Neurosci.* 18(10):3870-3896, May 1998.