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Scales of Neuronal Data and the Problem of Interaction

Cortical information processing was suggested to be performed via functional groups of cells, called cell assemblies [1]. Theoretical work supported this idea by indicating that synchronous input to a neuron is much more effective in emitting a spike than uncorrelated input. Although this coding scheme was controversially discussed, first supporting indications for spike synchrony were published, soon after techniques became available to simultaneously record from more than a single neuron. Presence of excess spike synchrony was found to be dynamic and related to behaviorally relevant instances in time. As expressed by different recording techniques (e.g. action potentials, local field potential (LFP)), the brain exhibits interesting phenomena on several spatial and temporal scales. However, the relationship of the various measures of cortical activity now experimentally available is largely unknown. The characterization of the joint signature of cortical processing in functionally meaningful contexts provides insight into the relevant scales and the potentially hierarchical organization of brain processes.

The mechanisms underlying neuronal coding and in particular the role of temporal spike coordination are hotly debated. However, this debate is often confounded by an implicit discussion about the use of appropriate analysis methods. To avoid wrong interpretation of data, the analysis of simultaneous spike trains for correlation needs to be properly adjusted to the features of experimental spike trains. Neuronal spiking activity is typically not stationary in time, but neurons 'respond' by changes in their firing rates to external stimuli or behavioral contexts. Also, data are not stationary across trials, but the statistical features may change during the experiment. Parametric approaches may be applied to experimental data to account for these aspects, however, the data may also contain features (e.g. deviation from Poisson) that do not allow an analytical treatment or parametric testing. Ignorance of such features present in parallel spike trains are potent generators of false positives, but can be avoided by including those features in the null-hypothesis of the significance test. In this context the usage of surrogate data becomes increasingly important to deal with such complex data [2].

The assembly hypothesis implies that entities of thought or perception are represented by the coordinated activity of (large) neuronal groups. However, whether or not the dynamic formation of cell assemblies constitutes a fundamental principle of cortical information processing remains a controversial issue of current research. While initially mainly technical problems limited the experimental surge for support of the assembly hypothesis, the recent advent of multi-electrode arrays reveals fundamental shortcomings of available analysis tools. Although larger samplings of simultaneous recordings from the cortical tissue are expected to ease the observation of assembly activity, it implies on the other hand an increase in the number of parameters to be estimated. It is usually infeasible to simply extend existing methods to such massively parallel data due to a combinatorial explosion and a lack of reliable statistics if individual spike patterns are considered. Due to limitations in the length of experimental data, in particular in respect to stationarity, all parameters of the full system cannot be estimated. Thus new concepts need to be developed and I will give a short review on the methods we developed that allow the analysis of massively parallel (hundred or more) spike trains for correlated activities [3].

Alternatively, one may directly observe a measure that reflects the activity of populations of neurons, as does the local field potential (LFP). It has been conjectured that LFP oscillations may represent an alternative network-averaged signature of assembly activations. With the aim to test this hypothesis we study and found that in different species and brain areas spikes are locked to the LFP and the locking may even increase with learning. Furthermore, we found that excess spike synchrony is much better locked to the LFP than chance synchronous events or individual spikes clearly indicating that significant excess spike synchrony reflects coordinated network activity on larger scales as expressed by the LFP [4].

In this presentation I will give an overview of the potential obstacles in the correlation analysis of parallel neuronal data and possible routes to overcome them.

References

[1] Hebb. The organization of behavior. John Wiley, 1949

[2] Grün (2009) Data-driven significance estimation of precise spike correlation. J Neurophysiol, 101, 1126-1140

[3] Grün & Rotter (eds) Analysis of parallel spike trains. Springer, 2010

[4] Denker, Roux, Lindén, Diesmann, Riehle, Grün (2011) Local field potentials reflects surplus spike synchrony. Cerebral Cortex (in press)