Flexible cortical gamma-band correlations suggest neural principles of visual processing

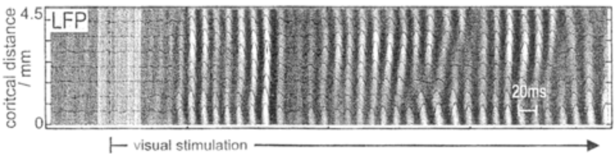
Reinhard Eckhorn und Kollegen 2001

Presentation in: Seminar on the Binding Problem, Sebastian Blohm, 17.06.02

Eckhorn et al. review in their study two experiments in which they perform measurements in humans and monkeys while presenting visual stimuli. They apply a new measure of and thus view on synchrony to yield larger correlation. In addition the results are compared to similar measurements in neural network models confronted with comparable input. I want to consider, in which way the results of these experiments allow argumentation in favour of binding by neural synchrony.

There are two major task in plausible binding-like information processing. For useful assembly coding, groups must not only be dynamically selected but also labelled in a way that subsequent processing stages can identify them as such.[1] Neural synchrony does both in an intuitive way: The construction of groups of synchronously firing neurons can be imagined to be the consequence of similar behaviour following similar input (together with the right interaction). After that it is plausible that higher processing stages identify neurons belonging to the same assembly by simply comparing their behaviour over time.

In the first experiment, Eckhorn et al. assess synchrony during a figure-ground segmentation task, asking: Do neurons in V1 representing together either figure or ground fire in a correlated way? As shown in preceding studies, measuring synchrony (by means of ɣ -coherence) would restrict binding to an area of a few millimetres on V1. To overcome this percepto-empirically implausible restriction Eckhorn et al. suggest ɣ-phase continuity as a measure of correlation. The experiment is conducted presenting a visual stimulus either homogenous or consisting of figure and ground. LFP measurements are taken from receptive fields at a given distance. When both represent either figure or ground, these receptive fields fire together at a common frequency with a phase that "at a given moment change continuously in space and vary randomly but smoothly in time" (see figure). This behaviour ("interpretable as long ranging ɣ-waves", p. 522) allows the ɣ-phase continuity measure to indicate correlation and accounts for ɣ-coherence's failure to do so (as variable phases here are averaged over).



In a second experiment further reaching (30mm) correlations are examined between patches of synchronous activity. They can be measured (subdurally in humans when performing a cognitive task) between slow potentials at one site and envelopes of ɣ-activity at another. These correlations are restricted to the point of time where a certain subtask (here: decision) is performed and is not present at points between these sites. Consequently correlation of ɣ-envelopes can possibly be seen as a relevant form of interaction.

Together these two experiments allow for both criteria of assembly coding mentioned above: dynamic selection and labelling. Spontaneous ɣ-coherence of "bound" figure/ground groups can be seen as selection and the at a fact that the envelopes of

[1] see Singer, 1999

these ɣ-waves interact with other brain regions indicates that it also can serve as a label for other processing stages.
Eckhorn et al. use two computer models of neural networks to reproduce the behaviour found in the experiments. The first one shows that synchronisation patches become spatially restricted when lateral travelling velocities of spikes are limited. The second "elaborate" model having basic properties of the cortex (feature preference columns, layers, retinotropic arrangement, connection to neighbours, inhibitory interneurons). With this model, the key effects observed in the experiments above can be found in an analogous manner: (a) Phase continuity of ɣ-waves within the representation of one object, (b) decoupling of ɣ-activities across object borders (both due to feature preference areas and lateral inhibition) and (c) the observed phase change across time and space (long ranging ɣ-waves) as well as (d) inter area communication.
The statement of this paper falls in two parts. The behavioural experiments show that and how synchrony exists and suggest what it might be good for. The neural network models provide relatively strong statements on which properties of neural wiring can make this kind of synchrony possible. Even though the mechanisms that underlie ɣ-coupling cannot be identified. (p. 524) The study suggests that neighbourhood on a cortical map is exploited to establish binding. In the case of figure-ground segmentation neighbourhood comes for free with the structure of V1. It remains an interesting question, if neighbourhood is always present when binding takes place especially how it comes about in multimodal binding.

References

> Eckhorn R. et. al. (2001). Flexible cortical gamma-band correlations suggest neural principles of visual processing. Visual Cognition 8. 519-530.
> Singer, W. (1999). Binding by Synchrony. Encyclopaedia of the Cognitive Sciences.
> diverse Nachschlagewerke ;-)