Traveling Gamma-Waves: Stimulus-dependent Signal Coupling in Monkey Primary Visual Cortex

Andreas Gabriel, Alexander Gail, Reinhard Eckhorn
Philipps-University, Department of Physics, NeuroPhysics Group, D-35032 Marburg, Germany
gabriel@hrz.uni-marburg.de

Introduction and Goal

The phenomenon of traveling waves in excitable neural structures is well known for a long time but its functional role in cortical sensory processing and coding is still unclear. During visual stimulation we found traveling plane waves in multiple-channel recordings from monkey striate cortex in the gamma-frequency range (30−90 Hz). Synchronized gamma-activity gained interest in recent years due to their proposed role in associative processing, including perceptual binding of object representations. However, gamma-synchrony in cat and monkey primary visual cortex (area V1) is restricted to few millimeters of cortical surface, challenging the synchronization hypothesis for larger cortical object representations (e.g. [1, 2]).

Methods

We developed a spatio-temporal correlation method capable of detecting and quantifying traveling waves from multiple-site recordings [3]. In the present investigation we analyzed multiple-channel local field potential (LFP) recordings from the striate cortex of awake monkeys during visual stimulation with grating textures, forming figure (object) and background.

Results

By applying this method, we demonstrate (1) that the spatial restriction of gamma-synchrony is due to the fact that the underlying gamma-signals are waves traveling in random directions across the representation of the visual object in V1; (2) that neural representations coding similar local features of the object surface are strongly coupled by gamma-waves (here: similar orientation preferences among the recording sites); (3) that the coupling dynamics of gamma-waves depend strongly on the continuity of the object's surface. This means that phase continuity of gamma-waves exists either inside or outside of the cortical representation of an object, but does not cross its boundaries.

Conclusions

From these and previous results [4] we suggest that the phase-continuity of gamma-waves can support the coding of object continuity and that the hypothesis of object representation by gamma-synchronization should be extended to more general forms of signal coupling and associative processing.

References

[1] Eckhorn, R. (1994). Oscillatory and non -oscillatory synchronizations in the visual cortex of cat and monkey. In Pantev, C., Elbert, T., and Lütkenhöner, B. (ed.), Oscillatory Event-Related Brain Dynamics, pp. 115−134. New York, London: Plenum Press.
[2] Frien, A. and Eckhorn, R. (2000). Functional coupling shows stronger stimulus dependency for fast oscillations than for low-frequency components in striate cortex of awake monkey. Eur J Neurosci, 12:1466−1478.
[3] Gabriel, A. and Eckhorn, R. (2003). A multi-channel correlation method detects traveling gamma-waves in monkey visual cortex. J Neurosci Meth, 131:171−184.
[4] Gail, A., Brinksmeyer, H.-J., and Eckhorn, R. (2004). Cereb Cortex, 14(3):300−314.

Supported by Deutsche Forschungsgemeinschaft DFG (FOR 254) to R.E