

Oscillations organize internally advanced cell ensemble sequences

György Buzsáki

Center for Molecular and Behavioral Neuroscience, Rutgers,
The State University of New Jersey, Newark, NJ 07102

How does the brain orchestrate perceptions, thoughts and actions from the spiking activity of its neurons? Previous single neuron recording research has regarded spike pattern variability as noise that should be averaged out to reveal the brain's representation of invariant input. An alternative view is that variability of spikes is centrally coordinated and that this brain-generated ensemble pattern in cortical structures is a potential source of cognition. Large-scale recordings from neuronal ensembles now offer opportunities for challenging and testing these competing theoretical frames. A postulated signature of the cell assembly is that its participants show a higher probability of spiking together than with members of other assemblies, even in the absence of external inputs. Interactions among parallel-recorded hippocampal neurons revealed a consistent temporal structure beyond that predicted from the environmental inputs. We find that prediction of spike times of hippocampal pyramidal neurons is improved using the spike times of simultaneously recorded neurons, over prediction from the animal's trajectory in space, or a spatially-dependent theta phase modulation. Thus, we suggest that the assembly organization arises from the internal dynamics of neuronal circuits. Assemblies are organized most efficiently within 10-30ms, suggesting that cell assemblies are synchronized at this timescale (gamma cycles). Seven to nine cell assemblies form assembly sequences within a theta cycle. The most active assembly occupies the trough of theta representing "here and now", flanked by representation of past and future events on the descending and ascending phase of theta, respectively. The "lifetime" of an assembly in the dorsal hippocampus is 1-2 sec, corresponding to 7 to 14 cycles of theta. In the absence of environmental inputs, the hippocampus continues to generate perpetually changing assembly sequences, which may represent the neuronal substrate of episodic memory. Interference with assembly organization by drugs, such as cannabinoids, affects episodic memory. Thus, assembly-based approach can provide an insight into centrally-organized (cognitive) events without reference to introspection and may be a powerful method for evaluating drugs affecting cognitive abilities.

References

- [1] Organization of cell assemblies in the hippocampus. Harris, K. D., Csicsvari, J., Hirase, H., Dragoi, G., and Buzsáki, G., *Nature* 424:552-556, 2003.
- [2] Neuronal oscillations in cortical networks. Buzsaki, G. and Draguhn, A., *Science* 304: 1926-1929, 2004.
- [3] Buzsaki G. Rhythms of the Brain. Oxford University Press, 2007
- [4] Forward and reverse hippocampal place-cell sequences during ripples, Diba K, Buzsaki G.. *Nature Neurosci.* 10:1241-2.