Resonance, cortical synchronization and (visual) information processing

Walter G. Sannita

Department of Motor Science and Rehabilitation, University, Genova, Italy;
Department of Psychiatry, State University of New York, Stony Brook, NY, USA;
email: 29537@unige.it

Characterizing features of the enhanced response of a system for some value of the input parameters (*resonance*) are nonlinearity and determination of its frequency by the intrinsic properties of circuit. With due approximation, the concept is extendible to brain function. Nonlinearity is peculiar to neuron and neuronal network properties and to functions at high level of complexity such as brain cortical dynamics, sensory information processing and 'cognition'. Resonant synchronization occurs in heterogeneous networks of neurons and sustain rhythms and the constancy of frequency, that depends on parameters of the inhibitory synaptic response (e.g. conductance peak and decay rate) and on discrete delays of the IPSPs onset; the threshold number of synapses/neurons needed for *resonance* to occur is small; reciprocally connected inhibitory neurons tend to fire synchronously if each one resets the firing patterns appropriately. Accordingly, spiking in bursts increases the reliability of communication between neurons by reducing the chances of synaptic failure; PSPs correlate with the interspike interval; IPSPs depend on the burst frequency and the cell frequency preference. In general, synaptic transmission is most effective when mediated by a specific resonant interspike interval.

The recruiting of neuronal networks in characteristic temporal and space scales is a fundamental in the episodic synchrony of signals that originate in discrete neuronal assemblies in concomitance of (experimentally defined) brain functions and oscillate at some given frequency. Subthreshold oscillations and *resonance* phenomena concur in cortical short-/long range synchronization and local specialization. The probability that neurons displaying spontaneous, sustained, subthreshold oscillations cluster in the same cortical slice is high. In a given slice, oscillating neurons oscillate in phase at the same frequency, that is determined by the membrane potential of the network rather than of single neurons.

Frequency-domain techniques describe oscillation as a fundamental behavior of neuronal function and signals and frequency as its natural unit of measure. An issue can be raised concerning the characteristic frequency of any given oscillating brain signal and the interaction among signals oscillating at distinct frequencies. The oscillations at ~20-80 Hz of the neuronal firing pattern and membrane/field potentials are an example in this regard. Oscillations in this frequency interval synchronize over large portions of visual cortex and mediate in the dynamics of segregated neurons activated by selective stimulus properties; are characterized in frequency, SNR, sources and source orientation in visual cortex; depend on (pre)synaptic visual input with a common mean phase; are independent from, anticipate in time dynamics the postsynaptic low frequency visual responses to which they contribute; reflect the stimulus global properties, with amplitude and latency being function of the stimulus contrast and spatial frequency consistent with the contrast function of the human visual system. In general, the ~20-80 Hz oscillatory response allows the required spatiotemporal accuracy for the activation of cortical neuronal functional assembly(ies) that are due to respond to sensory inputs or mediate in otherwise time-related brain processes. In a study on healthy humans, the ~20-80 Hz cortical response to contrast stimulation proved correlated with the phase-locking to visual input of the post-synaptic broadband response, with a correlation function across subjects that appears compatible with single-neuron models and the *stochastic resonance* theory and suggests some individual adaptation in visual processing.