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POSTER PRESENTATION **Open Access**

Role of STDP and heterogeneity in the emergence of long-range temporal correlations and frequency scaling in networks of LIF neurons

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The genesis and functional relevance of the long-range temporal correlations (LRTCs) and frequency scaling observed in the human EEG [1] have yet to be explained. Previous modeling studies have shown how dynamical synapses or short-term plasticity can lead to a self-organized critical state [2], however, the relevance of other mechanisms of plasticity and the role that heterogeneity of neuronal properties has to play in the observed statistics of brain activity remains to be fully explored. The issue of how network spikes and long-range temporal fluctuations and high-frequency scaling are related is still an open question.

We have developed a computational model showing how the action of spike-timing dependent plasticity (STDP) upon a network of tonically spiking neurons can lead to the appearance of frequency scaling above and below the preferred natural frequency of the neurons. Taking inspiration from statistical physics models where quenched disorder is associated with scale-free fluctuations we propose that diversity of neuronal properties act as a catalyst for avalanche dynamics and long-range correlations. With heterogeneity the network shows resistance to the fully phase coherent synchronous state. With the action of STDP upon a heterogeneous ensemble, the characteristic 1/f-spectrum and avalanche-like activity of self-organized criticality emerges for regions of the parameter space which describe an almost fully connected network and high variance in the neuron parameters and synaptic delays.

The model also shows how high and low frequency scaling can exist independently as constraints on network structure can affect the development of either scenario (see Figure 1).

In the presence of sparse connectivity, the network exhibits two regions of spectral scaling. The model allows features of the power spectrum to be directly related to the characteristic dynamics of network spikes and collective oscillations.

The mechanism shows robustness to noise and can be applied to more complex neurons with a non-linearity and an adaptive threshold as in the case of the adaptive exponential integrate-and-fire neuron model, suggesting

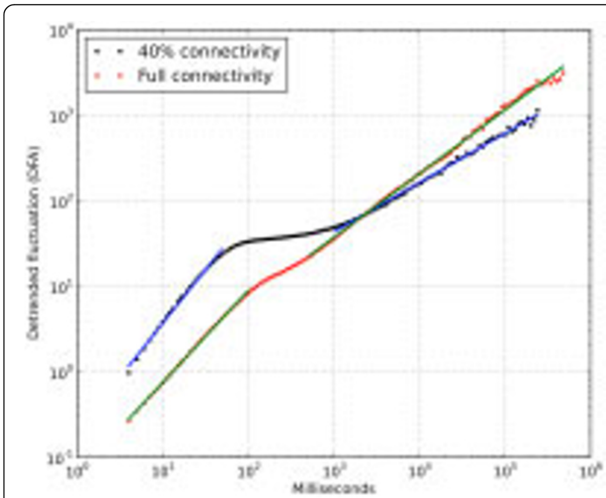

Figure 1 Detrended fluctuation analysis of the network activity shows the relationship of scaling regimes to constraints on plasticity of the network. Sparsely constrained networks are dominated by high frequency scaling whereas in dense networks the activity is correlated on a wider range of time-scales. Hurst exponents fitted to the data are: 100% connectivity: high-freq=1.1, low-freq=0.7; 40% connectivity: high-freq=1.3, low-freq=0.6. The neurons have a characteristic frequency at ~20 Hz.

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that it will scale up to apply to physiological situations and higher degrees of model complexity.

With STDP and heterogeneity, avalanches and bursts can become correlated with one another in time, giving rise to long-range temporal fluctuations up to the order of hundreds of seconds. This suggests how the observed avalanche-like activity observed in MEA (multi-electrode arrays) upon cortical slices [3] could be reconciled with the LRTCs and the 1/f spectrum of macroscopic EEG.

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