Human Cortical Power Law Amplitude Couples to $\theta$, $\alpha$ and $\beta$ Phase

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Having recently validated our hypothesis of functional changes in a cortical spectral power law with local activity in human cortex [1], we move to the significance of this finding. Using a PCA based method on electrocorticographic recordings in humans, we were able to decouple this power law behavior from the classic $\alpha$ and $\beta$ rhythms, revealing its presence at low frequencies. We examined the relationship of changes in the amplitude of this power law to the phase of intrinsic low frequency rhythms. Here we demonstrate that $\theta$ phase to high-$\gamma$ amplitude coupling [2] is not, in fact, limited to the high-$\gamma$ range. It is a property of the amplitude of this power law phenomenon, varies with changes in local cortical activity (between finger movement and rest), and locks to the trough of the phase of $\alpha$ and $\beta$ as well as $\theta$.

We show how a simple, small-scale, model of synaptic organization may provide intuition for the large scale phase-amplitude correlation we report. In this model: 1) The temporally scale free (power law) potential changes reflect asynchronous summation of a large number of cortico-cortical inputs between pyramidal neurons in the distal dendritic arbor. 2) Synchronous, sub-cortical (thalamic and other), projections to the proximal dendritic arbor of pyramidal neurons are reflected in the $\theta$, $\alpha$, and $\beta$ rhythms. The interaction of these two processes is then responsible for the phase-amplitude coupling we observe.

Figure: A) Power law (upper right) in the cortical spectrum can be extracted from alpha and beta peaks during a movement task, and its’ shift during activity can be visualized alone (lower right). B) This shifting power law is coupled more strongly to $\theta$, $\alpha$, and $\beta$ phase during inactivity than activity. C) A simple model is postulated where thalamic input shunts cortico-cortical interaction.

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References