Emerging of multidien-like rhythms using partial synchronization of phase oscillators

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In past years, the availability of recording devices of electroencephalography (EEG) have allowed studying epilepsy on much longer time-scales. The study of these recordings has shown that interictal spikes (IEA) and seizures fluctuate on long time-scales called ‘multidien’ that range from 4 days to 45 days[1]. This effect has been confirmed in other datasets, in other species [2,3], and even using different biometric signals[4]. However, contrary to what happens with the circadian rhythm, there is still no concrete explanation for how these long rhythms may arise. The fact that the periodicity of the multidien rhythms is heterogeneous across patients suggests that the multidien rhythm is unlikely to be generated as an evolutionary mechanism as the circadian rhythm. Here, we propose that these long time-scales may be generated by some hormone interaction cycling at a much faster pace, namely, the circadian rhythm. To test our hypothesis, we use a ring model of phase-oscillators[5] with non-local connectivity and we study how the synchronization of the network of oscillators changes in time. Using the circadian cycle as our natural frequency for each oscillator, we are able to generate multidien-like rhythms of the overall synchronization. Moreover, we found that by changing the broadness of the non-local connectivity and the phase-lag parameter, we can generate different significant periodicities. Additionally, by making this tuning, we are able to replicate the main clusters of multidien periods found in [1]. Finally, the model allows for the explanation of why all subjects, despite their different periodicity, lock their seizure time with the same phase of their multidien phase.

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