ABSTRACT OF THE DISSERTATION

On the waveform shape of neural oscillations

by

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Brain rhythms, or neural oscillations, are one the most prominent features of electrical brain recordings. Over the past century, they have been studied for their relationships to healthy behavior, neurological diseases, and physiological changes. Theories have developed for how these oscillations may play key roles in neural communication and computation. Many discoveries have been made by analyzing these rhythms using tools based on the Fourier transform, which decomposes the neural signal as a sum of rhythmic sine waves. However, the rhythms in these signals often have waveforms that significantly deviate from sine waves. Therefore, the standard Fourier decomposition may not be optimal for studying the potential meanings of these nonsinusoidal features. In this dissertation, I begin by reviewing the literature of the sparse reports of nonsinusoidal waveform shape and its potential physiological meaning. Using a dataset of motor cortical electrocorticography recordings from Parkinson’s Disease patients, I show that deep brain stimulation treatment decreased the sharp shape of the patients’ beta oscillations. Furthermore, I showed that this waveform shape change underlied past reports of phase-amplitude coupling, and that the coupled high gamma power was predominantly coming from the sharp extrema of the nonsinusoidal beta wave. Next, I propose a cycle-by-cycle analysis framework for analyzing the waveform shapes of oscillations across neural recordings. Finally, I apply this framework to study the sawtooth-shaped rodent hippocampal theta rhythm. I found that the waveform shape of this rhythm contained information about the firing rates, synchrony, and sequences of the local hippocampal CA1 neuron population. Rather than being a nuisance, I conclude that these nonsinusoidal features may provide critical, heretofore overlooked physiological information related to neural communication, computation, and cognition.