Characterizing Beta Event-Locked Oscillations in Human Electrophysiology Data

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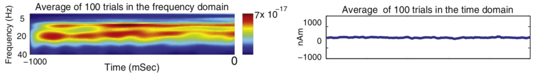
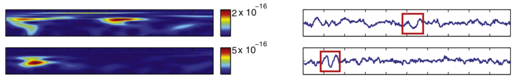
Introduction

Beta frequency rhythms (15-29 Hz) are prominent signatures of brain activity that can be measured using electro/magnetoencephalography (EEG/MEG). High beta activity is associated with inhibited tactile perception[1], and can be modulated through selective attention.[2]

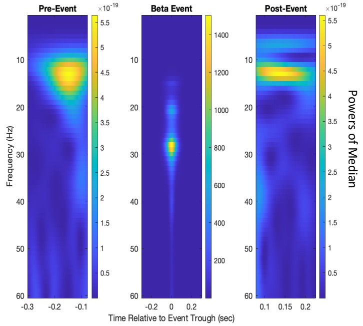
When averaged across trials, beta activity appears as an ongoing oscillation…



But individual trial analysis reveals that beta instead manifests as transient "events." [4,5]



These events have a stereotyped waveform shape, each lasting around 150ms with a prominent trough lasting 50ms, which is the period of beta.[3]



Spectrogram of averaged signals from pre, post, and during beta event time intervals

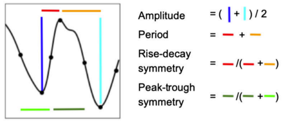
A novel finding in our lab is a lower frequency oscillation that appears to be phase locked to the beta event. We are interested in analyzing features of this waveform oscillation, and examining if there are differences across subjects or experimental conditions that predict tactile perception or shifts in attention. If so, we can use our lab's computational neural modeling framework (HNN) to study the neurophysiological source of these differences, providing an unprecedented link between novel measures of human information processing and their underlying circuit-level generators

Methods

Traditional signal analysis methods are based on the Fourier transform, which models neural data as sums of component sinusoids.

Here our aim is to identify non-sinusoidal characteristics of MEG data collected by our lab. To do this, we employed a tool developed by the Voytek lab at UCSD (GitHub link) that quantifies oscillatory features in the time domain on a cycle-by-cycle basis.[6]

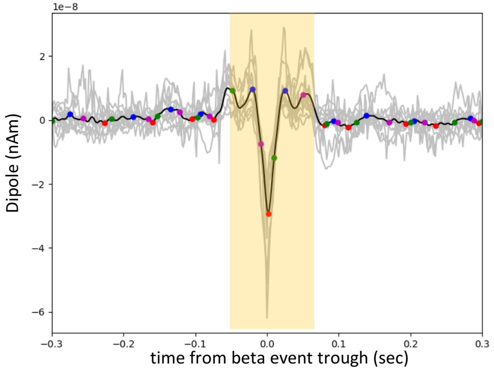
Raw Data → Adjust Filters and Parameters → Reflect signal to Remove Edge Effects → Run Analysis to Extract Features → Analyze Features of Interest



Examples of features that can be analyzed through cycle-by-cycle analysis.[6]

Waveform Shape Analysis

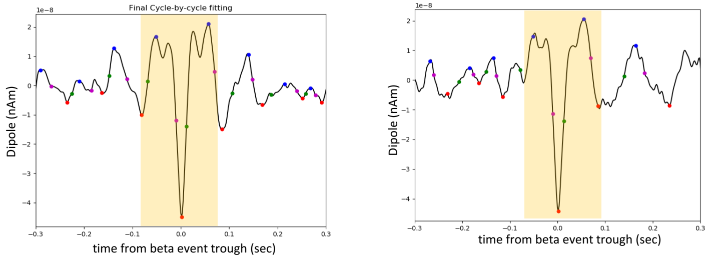
Grand Average Across Subjects Aligned to Beta Event Trough Shows Oscillation Locked to Beta Event



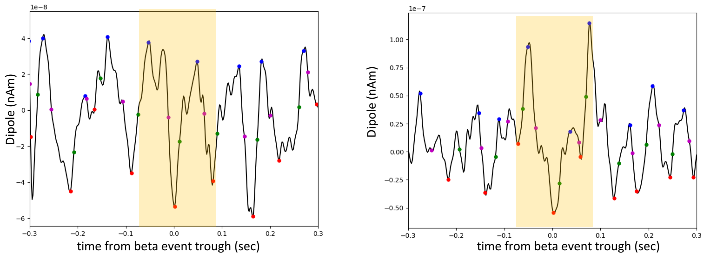
Red: Trough (Relative Minima)
Blue: Peaks (Relative Maxima)
Green: Rise segment midpoint
Purple: Decay segment midpoint

Example Cycle-by-cycle analysis output with Beta event highlighted

Waveforms Averaged Across Trials for Individual Subjects Show Individual Differences in Waveform Shape That Can Be Analyzed Between Subjects With Respect to Differences in Detection Performance, Attention, Age, Etc.

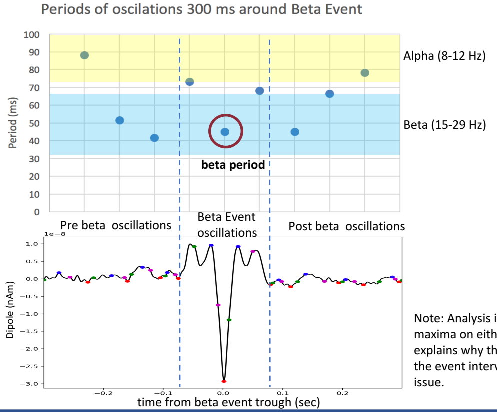


Waveforms in Single Trials From Individual Subjects Show That Locked Oscillations are Evident Even on Single Trials, and Thus May be Used to Predict Behavior Within Subjects



Waveform Feature Analysis

Initial Results Suggest Beta Event-Locked Oscillations Vary from the Alpha- to Beta-Band Frequency



Quantifying the period of each cycle in the grand average signal reveals that as the phase-locked oscillation approaches the beta event, the frequency appears to increase from the alpha (8-12 Hz) to the beta range (15-29 Hz).The opposite pattern is observed following beta event.

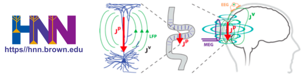
Note: Analysis is not classifying apparent second maxima on either side of the beta trough. This probably explains why there appears to be alpha activity within the event interval. We are currently troubleshooting this issue.

Future Directions

Further quantify phase-locked oscillations across trials and subjects, and assess other non-sinusoidal features of our data using this analysis.

Carry out statistical analyses to test differences before and after the beta event, as well as across behaviorally relevant conditions in a tactile detection/attention task.

Employ Human Neocortical Neurosolver (HNN), a unique modelling software developed by the Jones lab, to test potential mechanisms underlying differences in waveform shape across subjects and conditions.



Use results to inform our transcranial magnetic stimulation (TMS) study, where we aim to mimic the inhibitory effects of endogenous beta events on tactile detection.

Acknowledgements

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References

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