Uncovering the role of transient neural oscillations during movement

Joseph Aguilera[1], Nigel Anderson[1], Bryan Natividad[1], Aryan Patidar[1], Connor Staggs[1], Nicholas Tolley[1]

[1]Brown University Data Science Initiative

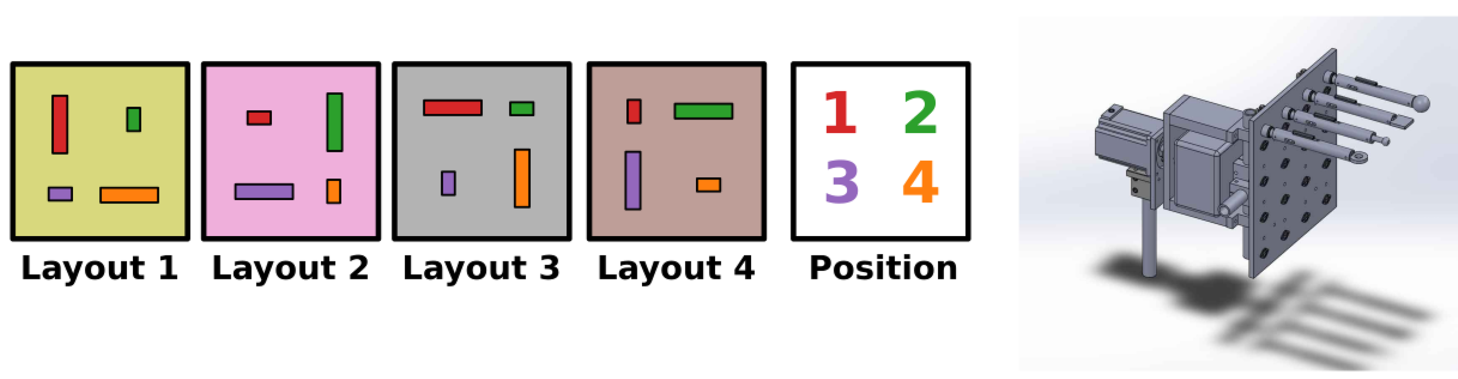
Introduction

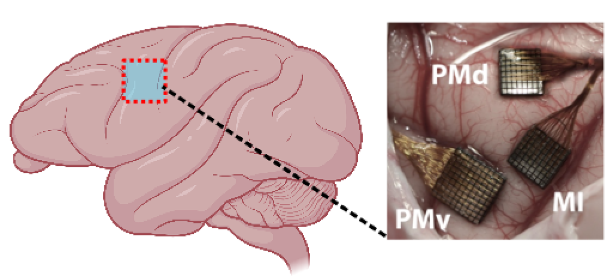
Neural oscillations refer to a large category of brain signals that are produced by the **synchronous activity of a large number of neurons** [1]. In recent years, it has been shown that many of these "oscillations" actually present as brief bursts of activity that we term **spectral events** [2]. Further, it has been shown that features like the timing and frequency of these spectral events play an important role in sensory perception, notably tactile perception [3]. However, **the role of spectral events in movement remains largely unknown**. In this study, we examine the role of spectral events in the brain region responsible for movement and assess how different features of spectral events are related to the types of movements being performed.

Methods

Behavioral features: reaction time and reach time

Monkeys trained to perform an **instructed delay reach to grasp** task consisting of: 1) target cue, 2) delay period, 3) go cue





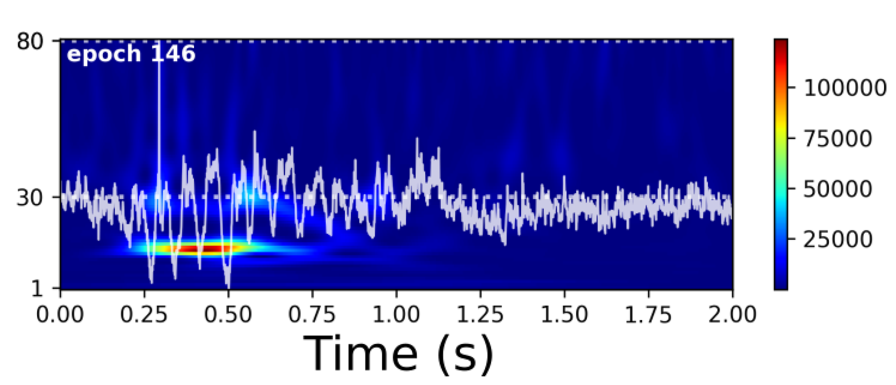
Electrode arrays implanted in **motor cortex**

"Quiver" Toy where cues are given to grab/pull different objects

α (8-12 Hz)
β (13-29 Hz)
γ (30-80 Hz)

Spectral events (transient increases in power) of 3 different frequency bands analyzed in the voltages recorded by implanted electrodes

Example of spectral event (**red blob**) in the beta frequency band



Neural features: peak power, event length, frequency span, peak time, peak frequency, and count
(mean ± std : 12 features x 3 frequency bands = 36 features)

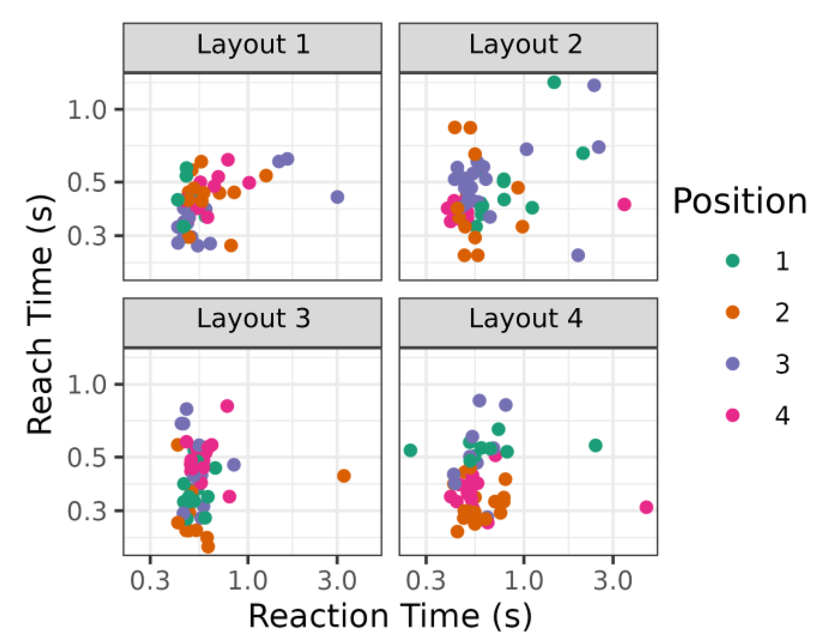
Linear/logistic models: used to relate neural (β) to behavioral features

$$ReactionTime \sim \beta_0 + \beta\,(NeuralFeatures) + error$$

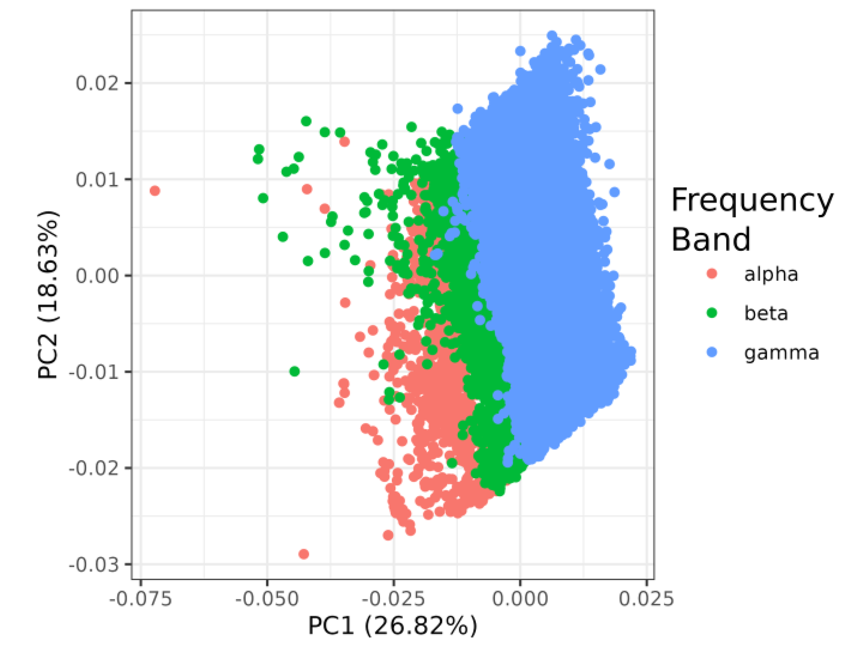
$$ReachTime \sim \beta_0 + \beta\,(NeuralFeatures) + error$$

Forward/backward selection with AIC used to identify best predictors

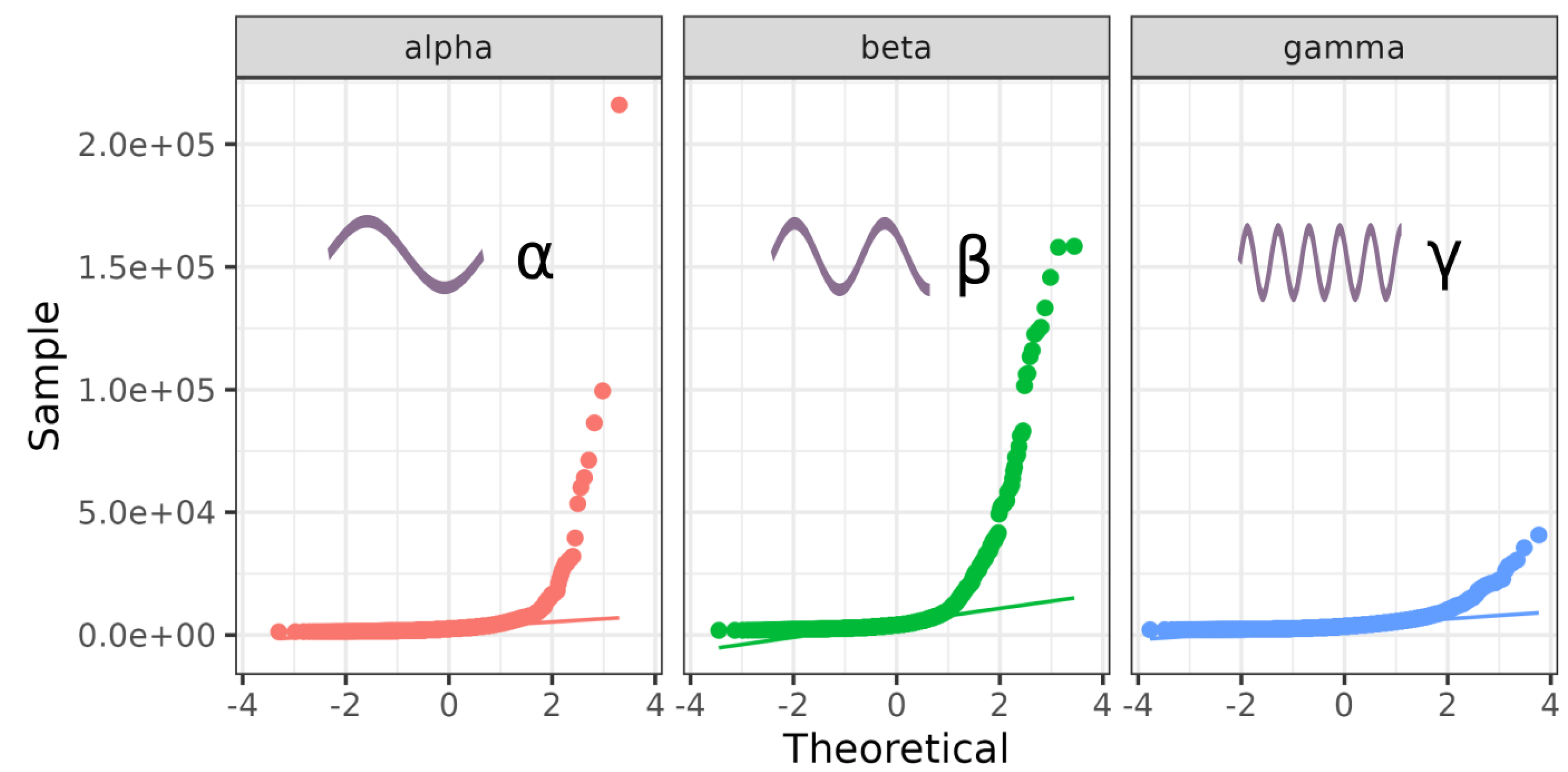
Exploratory Data Analysis



Behavioral features show a subtle separation by position/layout

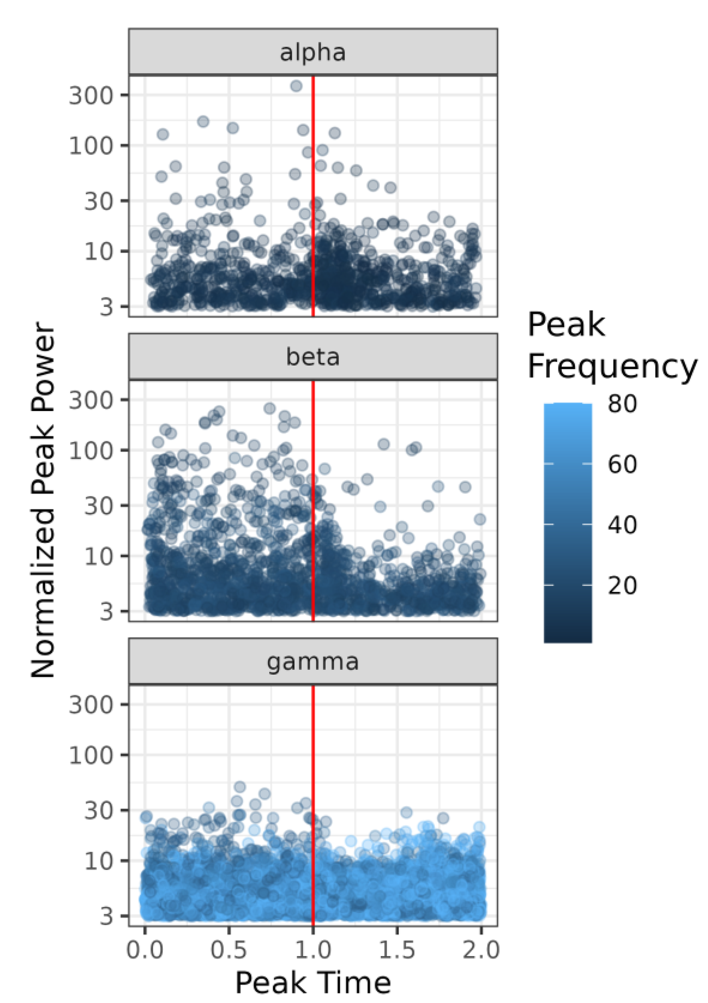


PCA applied to neural features show separation is largely determined by frequency band

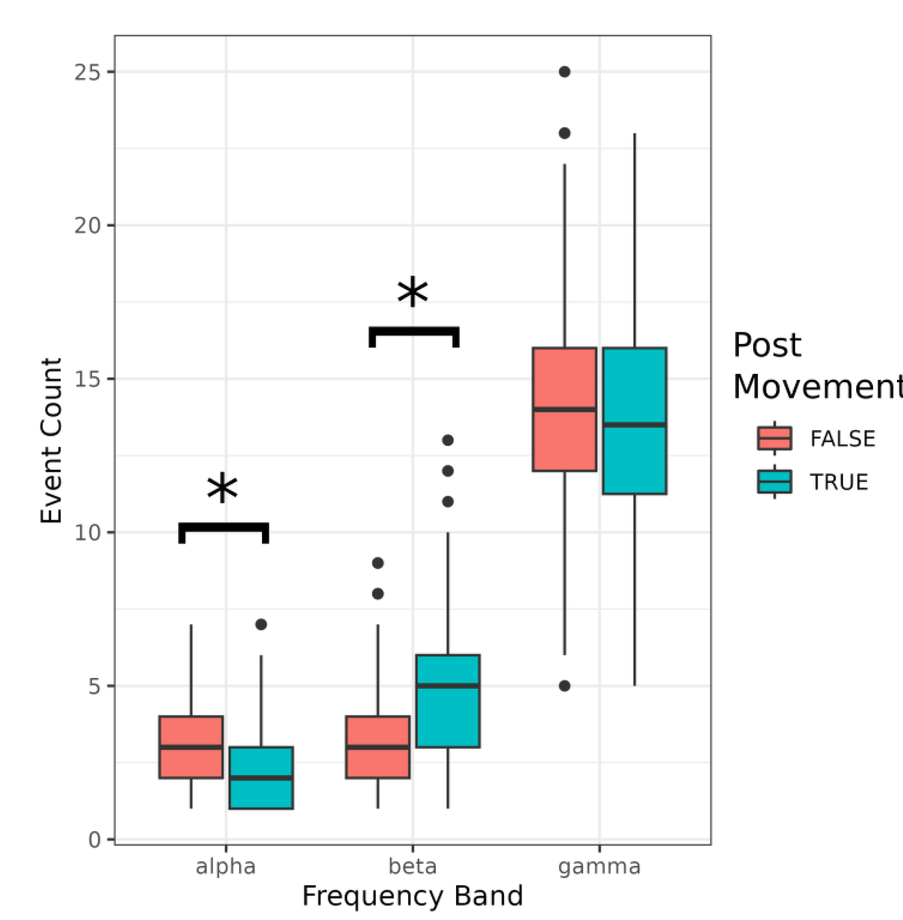


QQ Plot for peak power feature exhibits a strong rightward skew (necessitating a log transform)

Alpha and Beta event frequency change pre/post movement

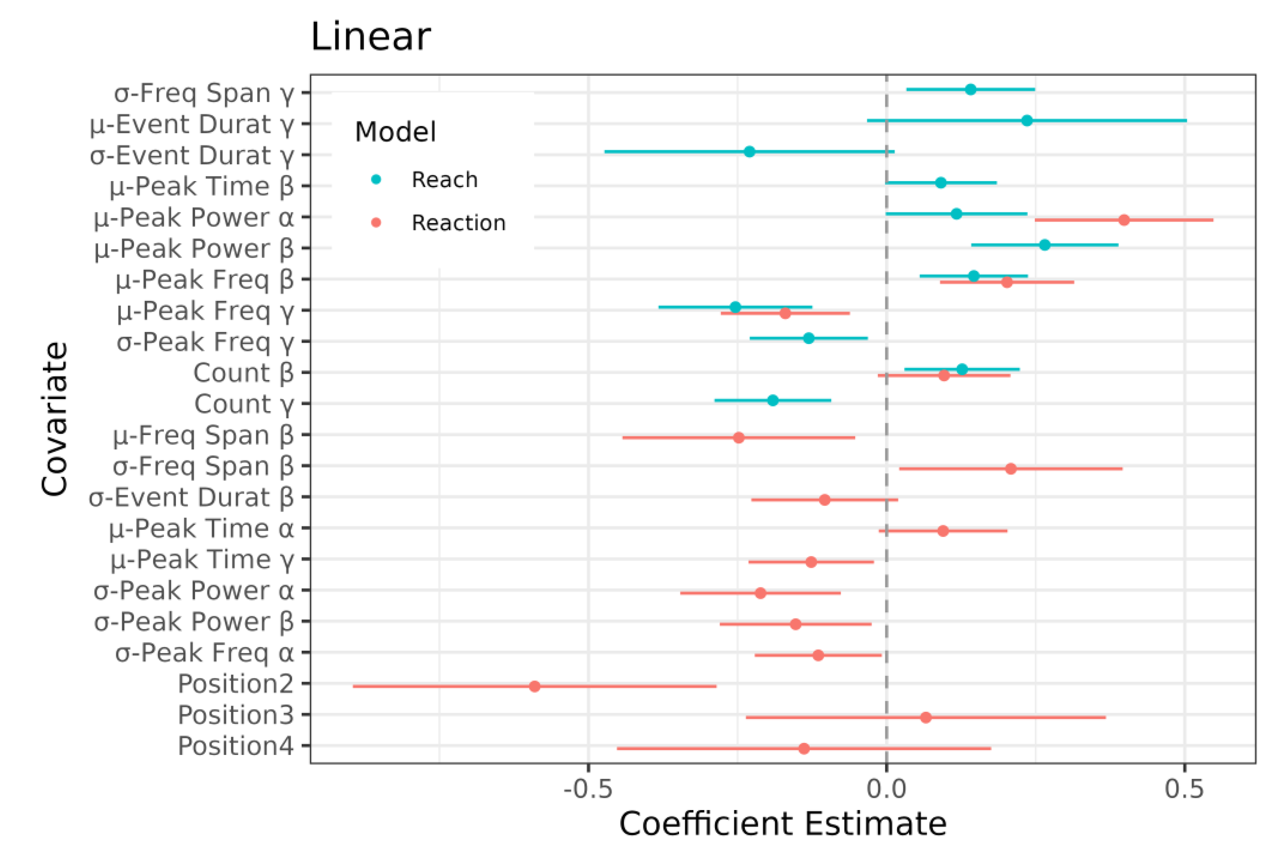


Each frequency band exhibits a distinct pattern before and after go-cue (red line)

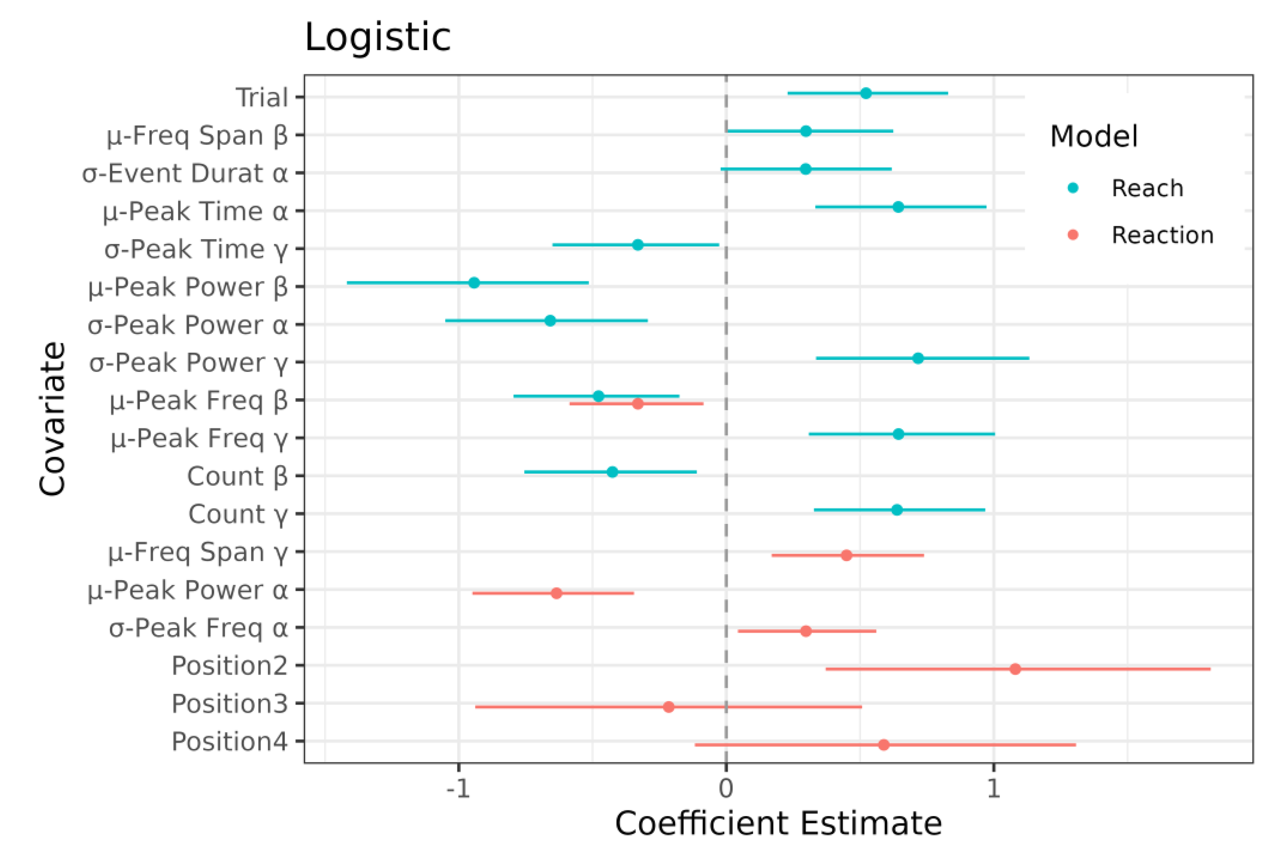


Welch two sample t-test shows that **alpha and beta** event counts **significantly differed pre and post go-cue**

Reaction/reach time best predicted by different neural features



For linear regression: **non-overlapping sets of features for all frequency bands** are best predictive of reach and reaction time (AIC Reaction: -73.166; Reach: -14.426)



For logistic regression: **trial** (which contains time information) is predictive of **slow/fast reach times** (AIC Reaction: 231.41; Reach: 286.37)

Position (where the monkey is reaching) is highly predictive of **slow/fast reaction times**

References

[1] Buzsáki et al., *Nature* (2012) [2] Jones, *Curr. Opin. Neurobiol.* (2016) [3] Shin et al., *eLife* (2017)

Acknowledgments

Data Preprocessing/EDA: J.A.; N.A.; B.N.; A.P.; C.S.; N.T.
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Regression Analysis: J.A.; B.N.; A.P.

Experiments and data collected in the labs of John Donoghue and Carlos Vargas-Irwin

GitHub Repository
https://github.com/ntolley/data2020_final_project