

# Replay of Learned Neural Sequences and Speech Decoding in Human Motor Cortex Observed Using an Intracortical Brain Computer Interface

Daniel B. Rubin<sup>1,2</sup>, Tommy Hosman<sup>3,4</sup>, Jessica N. Kelemen<sup>1,4</sup>, Anastasia Kapitonova<sup>1,4</sup>, Francis R. Willett<sup>5</sup>, Brian F. Coughlin<sup>1</sup>, Eric Halgren<sup>6</sup>, Eyal Y. Kimchi<sup>1,2</sup>, John D. Simeral<sup>3,4</sup>, Leigh R. Hochberg<sup>\*1,2,3,4</sup>, Sydney S. Cash<sup>\*1,2</sup>

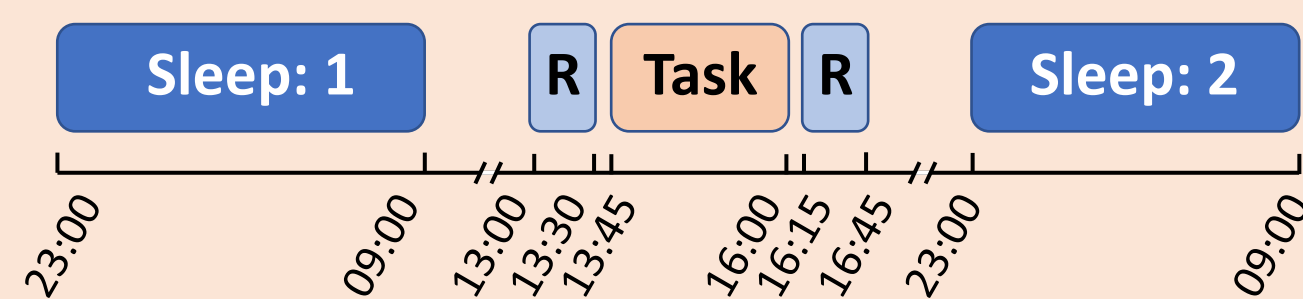
1. Center for Neurotechnology and Neurorecovery, Dept. of Neurology, Massachusetts General Hospital, Boston, MA. 2. Harvard Medical School, Boston, MA. 3. Center for Neurorestoration and Neurotechnology, Dept. of Veterans Affairs, Providence, RI. 4. Carney Institute for Brain Science and School of Engineering, Brown University, Providence, RI. 5. Howard Hughes Medical Institute at Stanford University, Palo Alto, CA. 6. Depts. of Neurosciences and Radiology, University of California at San Diego, La Jolla, CA. \*Co-senior Authors.

## Background/Motivation:

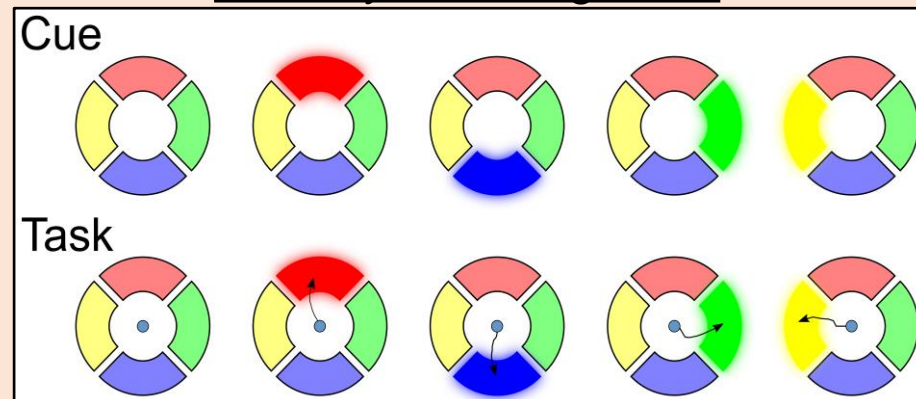
- Offline replay of task-related neural activity has been proposed to underlie learning/memory; though well documented in rodents, replay is less explored in humans.
- We explored whether learned neural activity patterns underlying a motor task using an intracortical brain-computer interface are replayed in motor cortex during sleep.
- We found that the neural activity patterns driving completion of a motor task are replayed in human motor cortex during slow-wave sleep.**
- In a second experiment, we recorded from motor cortex as the participant spoke to complete a verbal matching task.

## Methods/Experimental Design

- 36 y/o M w/quadruplegia enrolled in the BrainGate pilot clinical trial had two 10x10 microelectrode recording arrays chronically implanted in left precentral gyrus. Additionally, EEG was recorded to track sleep stages.
- In the first experiment, neural activity was recorded **while performing repeated motor task** and **while sleeping** the night before and after day of motor task performance.

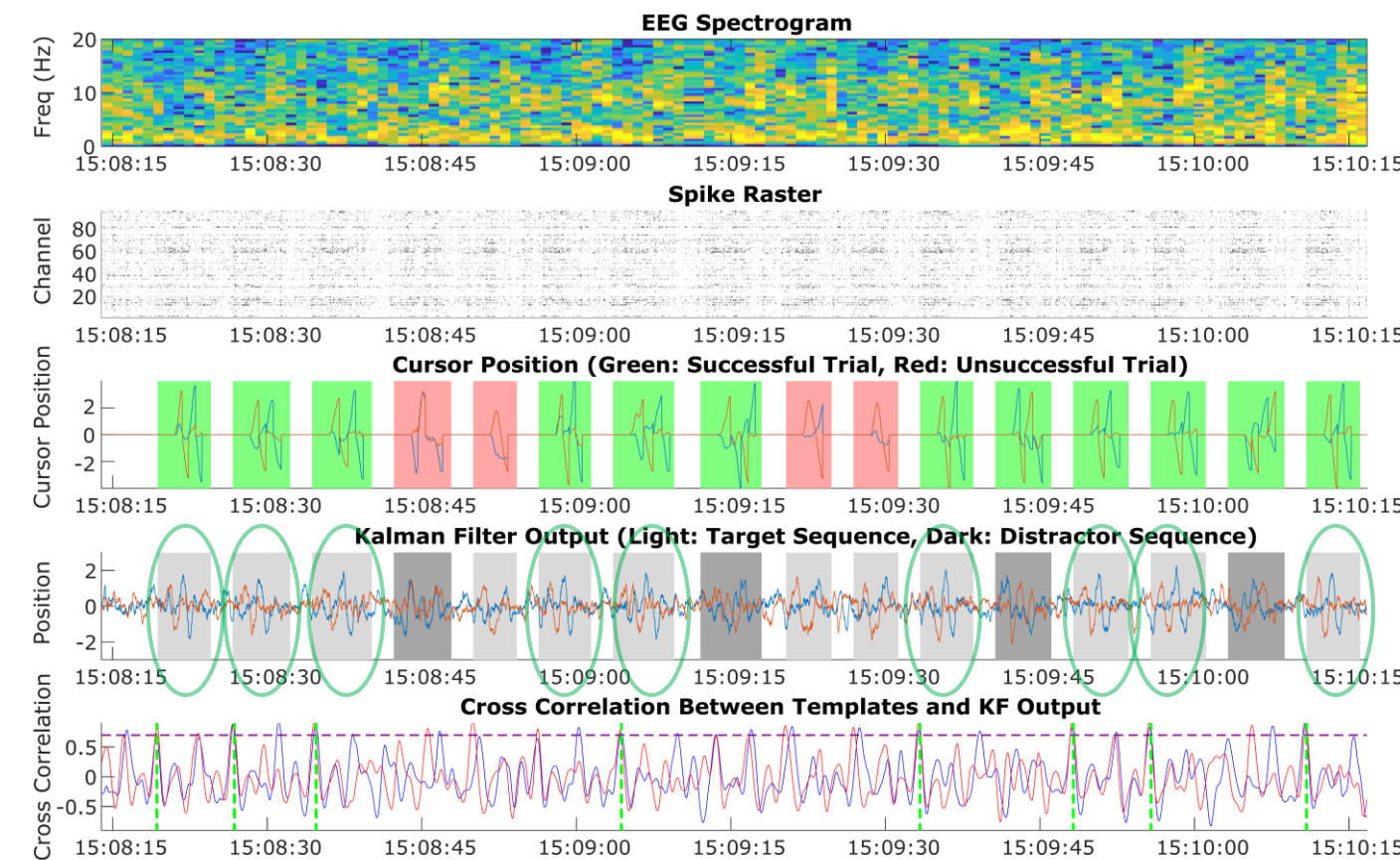


### Memory Matching Task:



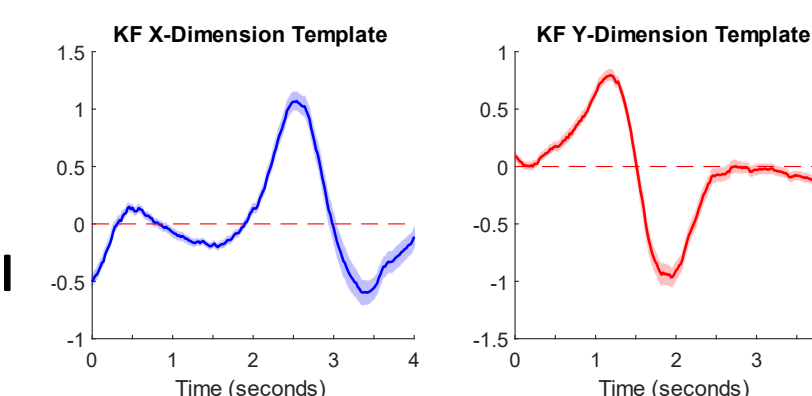
- Motor task:** move neurally-driven cursor to targets in the same order as presented.
- Ten rounds, 16 sequence trials per round (75% trials are target sequence; 25% distractor sequences).
- In the second experiment, the participant read a list of words as they were presented on a screen; eight words were each repeated 140 times while recording the associated motor cortical neural activity.

## Analysis/Results



- Neural activity drives an on-screen cursor via a steady-state Kalman filter (KF) model:
- Mean KF output from successful target trials (green ovals) used to build target templates:
- Cross-correlation was calculated between target templates and KF output at each time step.
- Instances where CC simultaneously >99<sup>th</sup> %tile in both X- and Y- dimensions deemed “Threshold Crossing Events”:

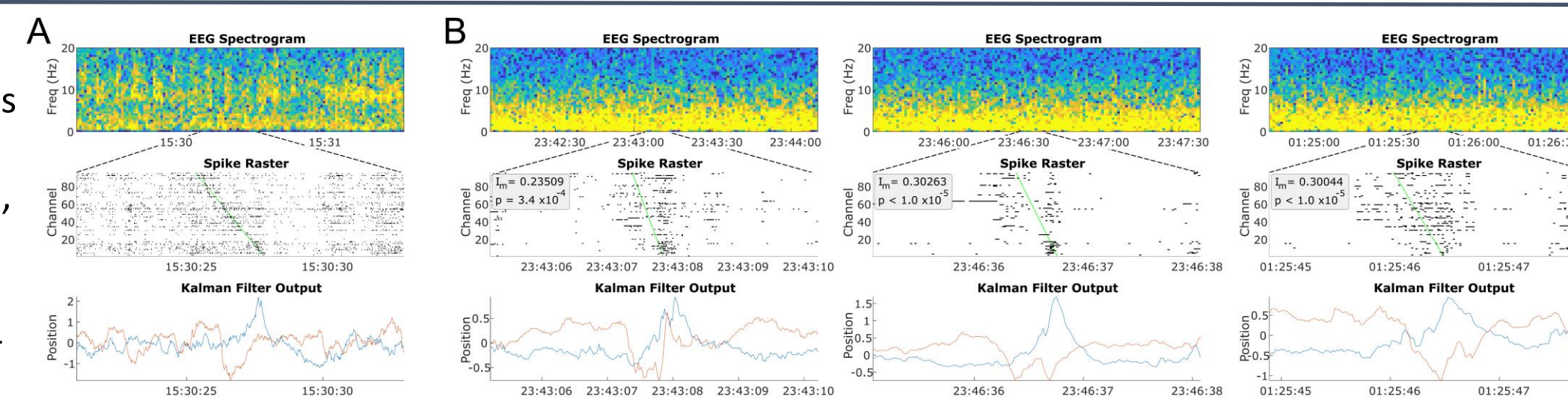
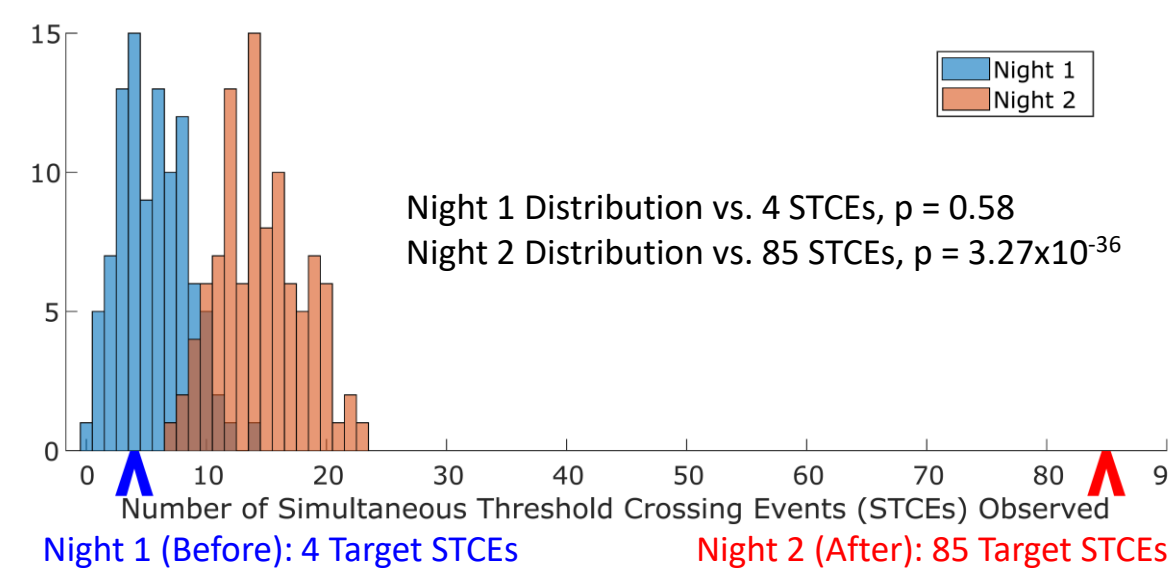
Vertical green lines indicate simultaneous 99<sup>th</sup> percentile simultaneous threshold crossing events (STCEs): STCEs are the neural activity driving successful task completion (putative replay).



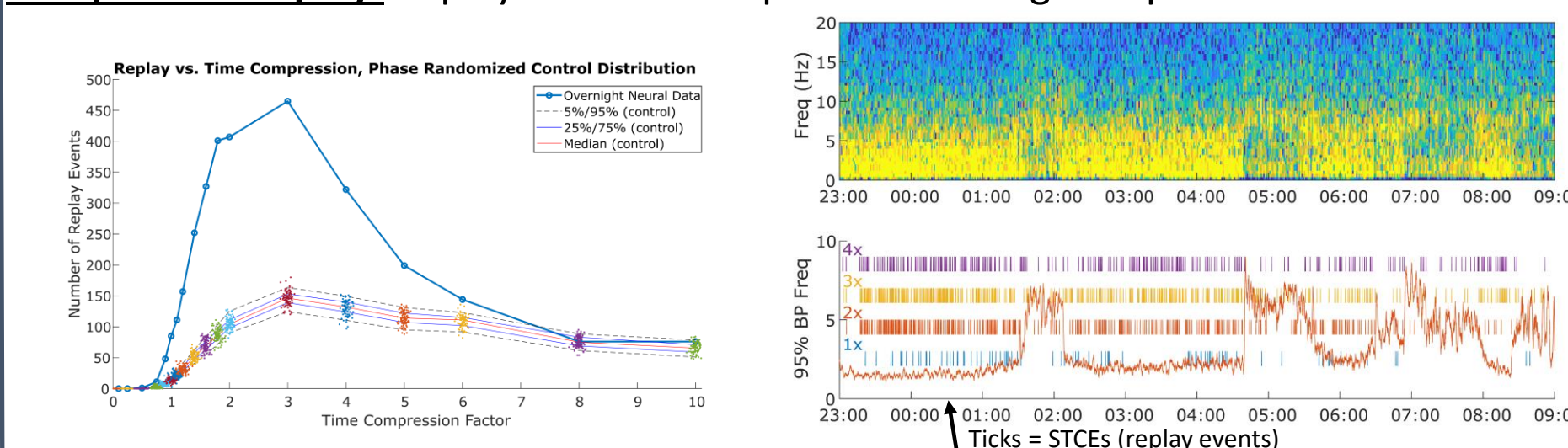
### STCEs as evidence of offline replay.

- Night 1: BEFORE task performance, 4 TCEs are observed.
- Night 2 (below): AFTER task performance, 85 TCEs occur.

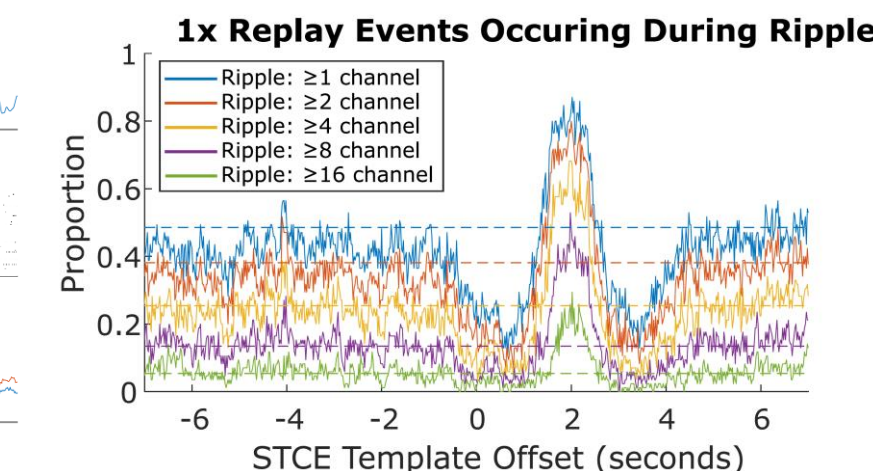
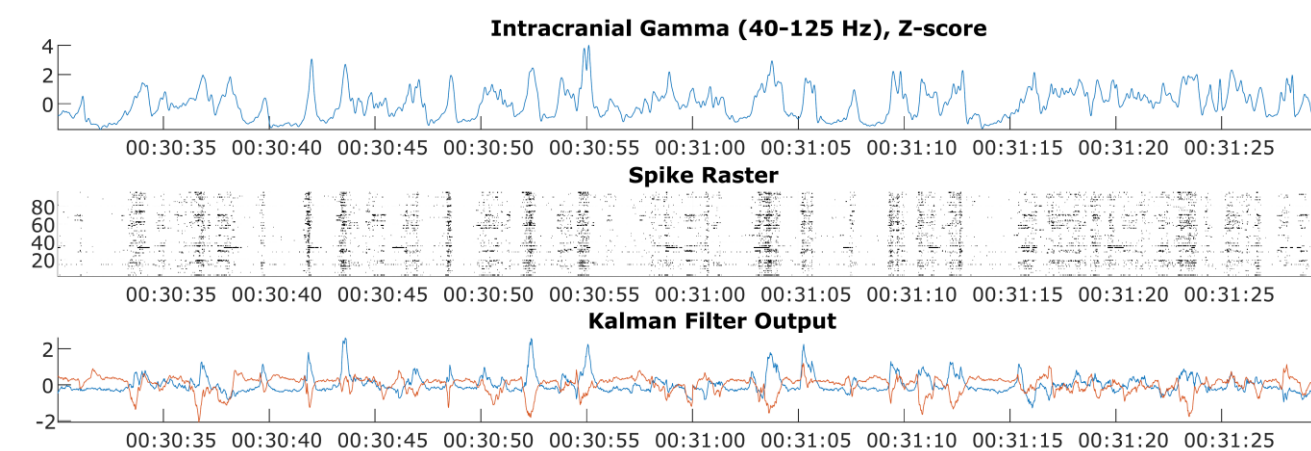
**Bootstrap Control:** #TCEs expected by “chance” by randomizing phase between X- and Y- dimensions of KF output:



### Compressed Replay: Replay occurred at speeds matching task performance or faster.

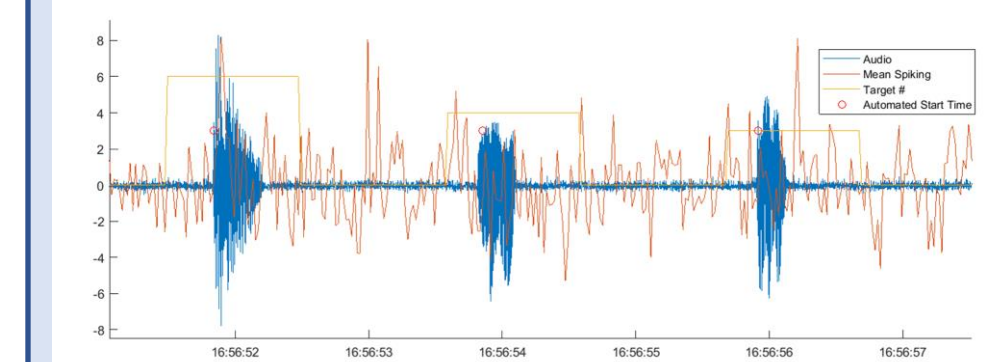
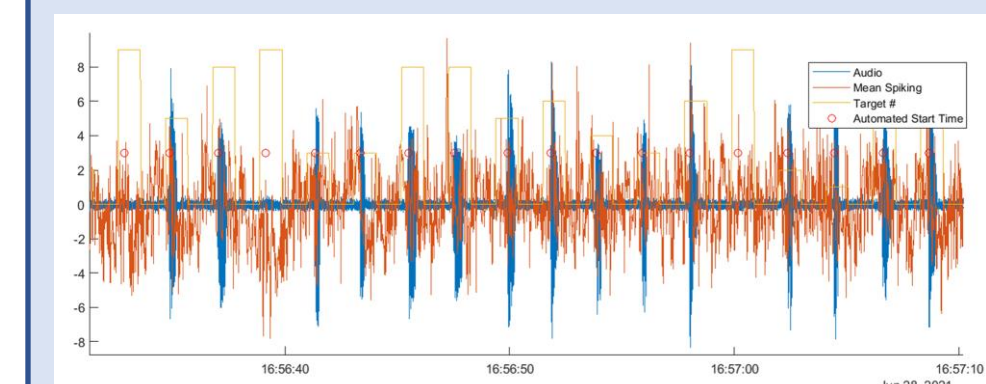


- STCEs occurred throughout the night during periods of increased low gamma range power.
- Using an automated detector, we find that sleep replay events occur preferentially during cortical ripples.

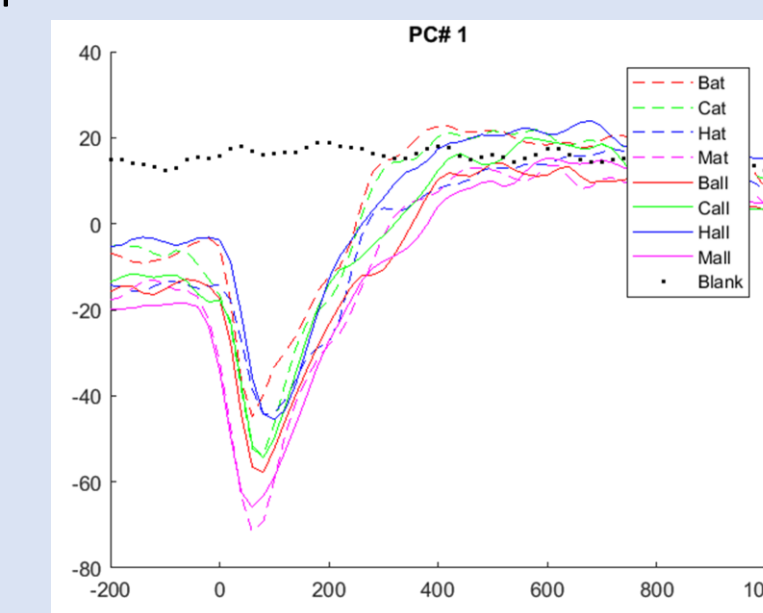


## Speech Decoding

- In a spoken word matching task, we record motor cortical neural activity and can now begin to decode intended speech directly.
- These AI algorithms will be used to drive direct thought-to-speech BCI to restore communication to patients with anarthria and other forms of paralysis.



- The neural activity dimension with greatest variability contains highly discriminative information regarding speech onset and initial consonant sound



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