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

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/quadriplegia 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.
- 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
- 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: STCEs expected by "chance" by randomising phase between X- and Y-dimensions of KF output:
- 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% "stable" in both X- and Y-dimensions deemed "Threshold Crossing Events" (STCEs). STCEs are the neural activity driving successful task completion (putative replay).

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.

Funding:
- U01NS098968
- R25NS065743
- DBR: NINDS
- SS: NINDS
- AAN Clinical Research Training Scholarship, Harvard Catalyst U34TR002345
- Career Development Award, Department of Veterans Affairs (A2295R)
- CARES, Office of Research and Development, Rehabilitation R&D Service, Department of Veterans Affairs (K23CS120916, K23HS024800, K23RR033985)
- This content does not necessarily represent the official views of the US Department of Veterans Affairs or the US Government.