# Identifying Changes in Volitional State and BCI Task Engagement Based on the Intrinsic Structure of Neural Ensemble Activity Patterns in Motor Cortex of People with Tetraplegia

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## INTRODUCTION

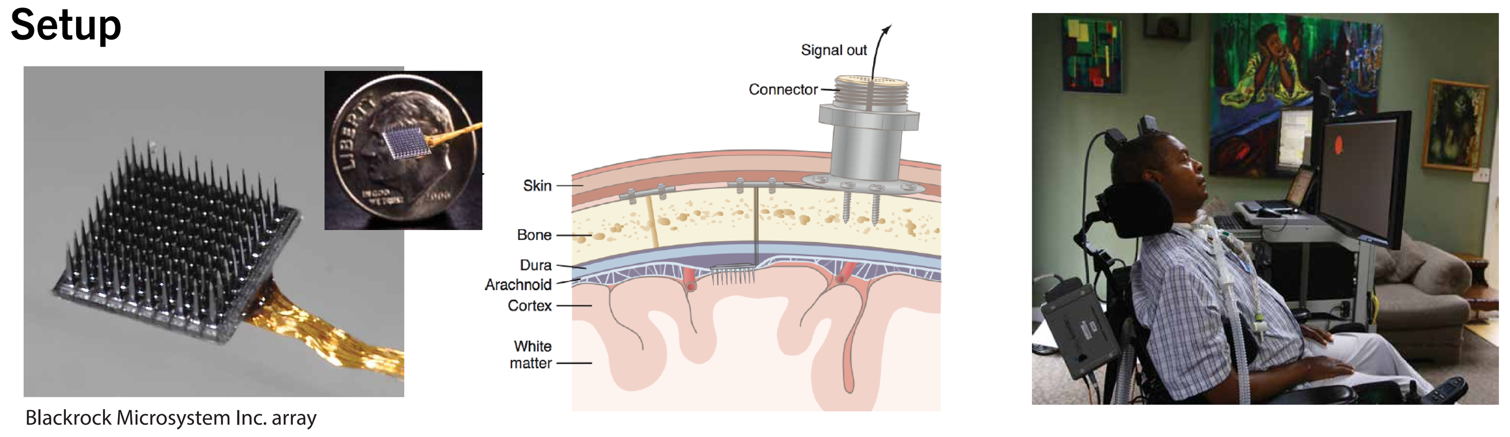
- Brain-computer interfaces (BCIs) are designed to bypass damaged motor pathways and provide new links to assistive technologies for people with neuromotor deficits.
- It is widely accepted that motor cortex incorporates a mix of incoming sensory, cognitive, and motor planning information, reflecting latent variables that are not directly related to kinematic motor output.
- There is a need to reliably identify neural activity patterns indicative of a set of latent factors affected by task and cognitive context changes to build BCI systems that support continuous, multi-effector use.
- Studies previously showed successful decoding of contextual changes in idle vs. active states (Lesenfants et. al, SfN, 2016), and controlling different end effectors (Fasoli et. al., APMR, 2017).
- We present clustering of the projections of neural data representing different context-dependent volitional states using an approach that visualizes data by generating low-dimensional state spaces based solely on the intrinsic similarity of single unit ensemble recordings.

## BACKGROUND & METHODS

**Participants** (enrolled in BrainGate2 pilot clinical trial, IDE*)

- T9: 52 year-old male with tetraplegia due to amyotrophic lateral sclerosis (ALSFRS-R of 8). Two 96-channel microelectrode arrays implanted both on left precentral gyrus (PCG).
- T10: 35 year-old male with tetraplegia due to spinal cord injury (C4 AIS-A). Two 96-channel microelectrode arrays, one each on the left middle frontal gyrus (MFG) and left PCG.

### Setup




### Data Acquisition

(a) center-out task controlled with a computer cursor
(b) center-out task controlled with a JACO robotic arm
(c) grid task

**(1) Full day continuous neural recording of BCI use and daily activities**

- 26-hour continuous wireless recording from T10 performing center out task (a), grid task (c), and other daily activities

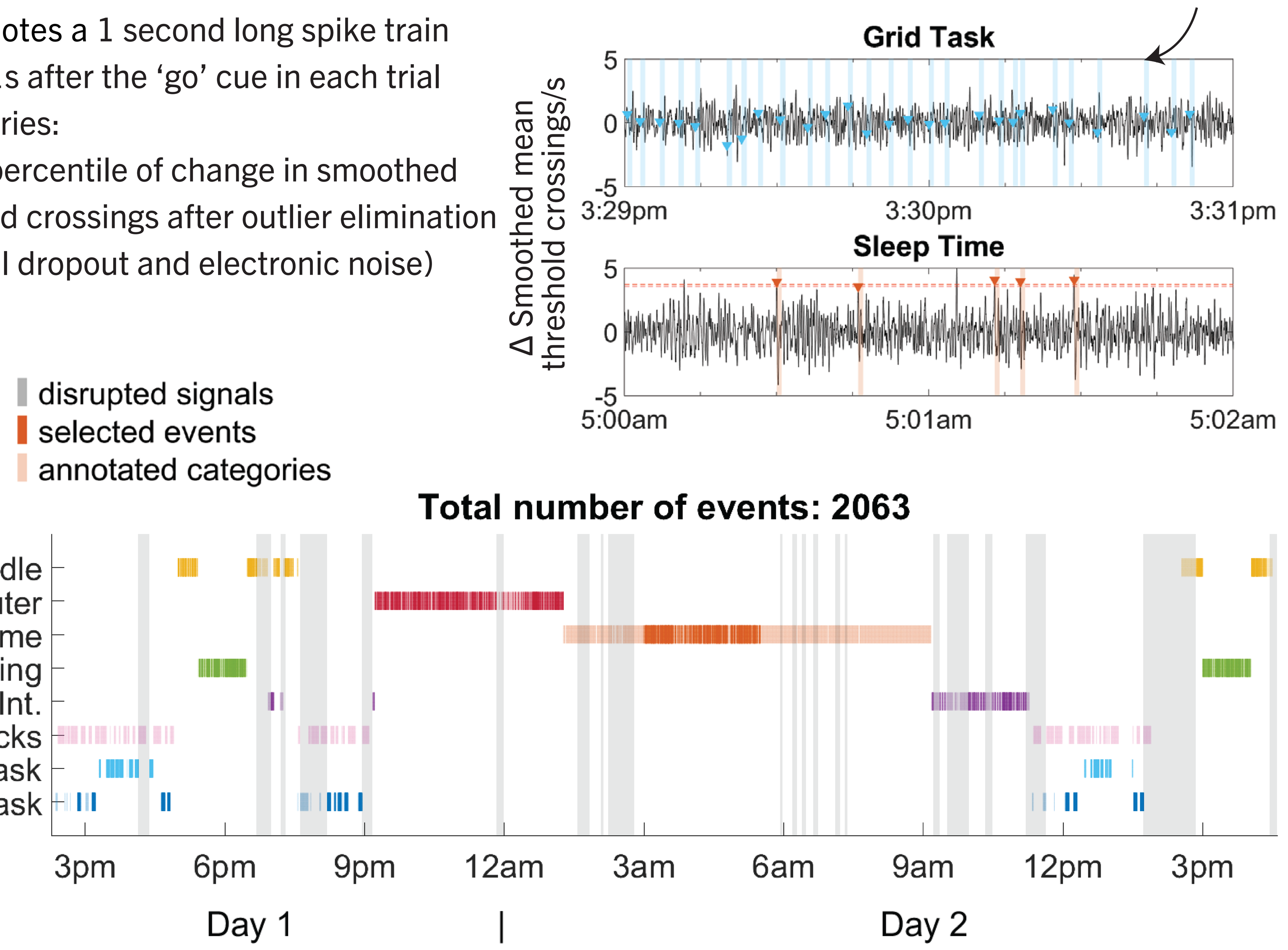
**(2) Cursor vs robotic arm control**

- In each recording session (8 for T9 and 4 for T10), the decoder was first calibrated on one effector using open-loop imagery and then closed-loop decoder calibration. The decoder then ran on blocks (each consisting of many trials of the same task) that alternated between the two effectors.
- Participants were instructed to move either a computer cursor (a) or a JACO robotic arm (b) to a cued target with no instructed delay in a center-out task.

## DATA SELECTION: 26-HOUR RECORDING

### Identify significant events to generate SSIMS space

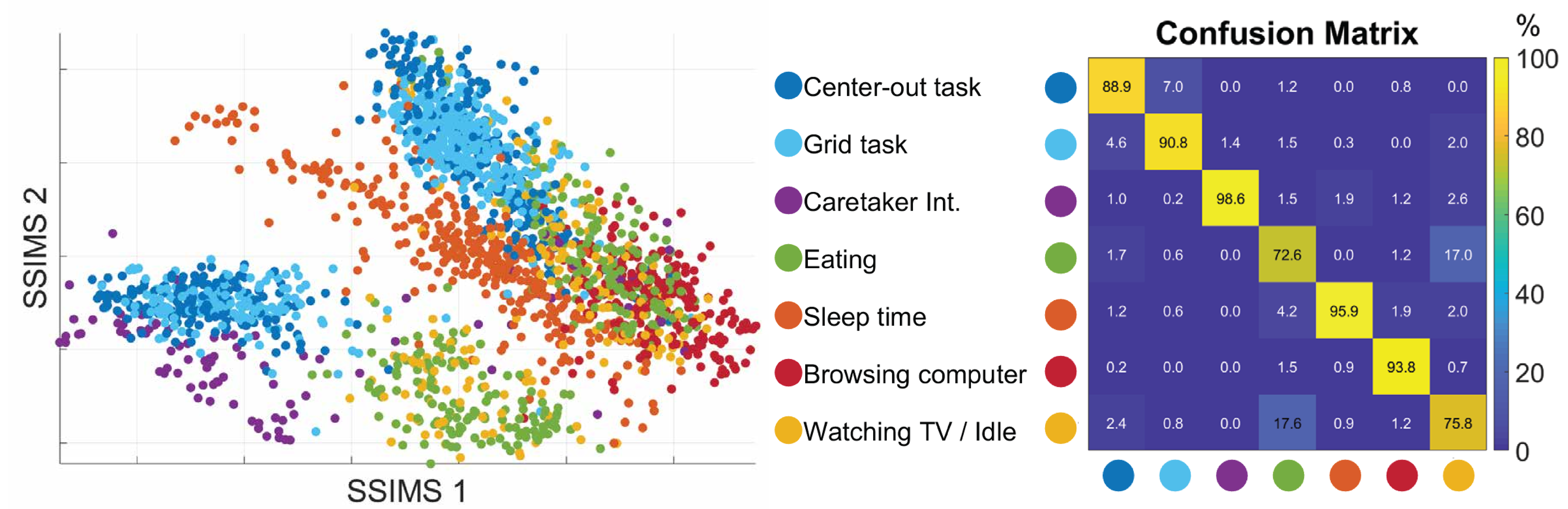
- each event denotes a 1 second long spike train
  - Tasks: from 1s after the 'go' cue in each trial
  - Other categories: events in top percentile of change in smoothed mean threshold crossings after outlier elimination (to avoid signal dropout and electronic noise)




## RESULTS: 26-HOUR RECORDING

### Neural events cluster by volitional state

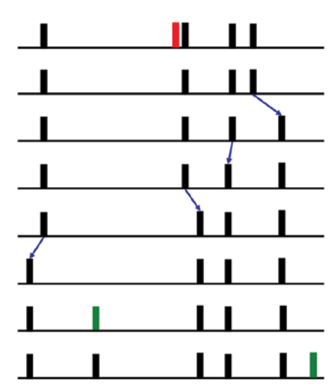
- 10-fold cross validated 5-Nearest-Neighbor (KNN) of 7 states: 81.18% ± 2.38% (chance: 17.82% ± 2.95% )
- Eating and watching TV difficult to separate; potentially because T10 was watching TV while eating




## METHODS

### Spike Train SIMilarity Space (SSIMS) (Vargas-Irwin et. al., 2015)

- Step 1: compute similarity metrics between pairs of spike trains by calculating the cost to transform one spike train to another with inserting, deleting, or shifting spikes (Victor and Purpura, 2011)
- Step 2: perform dimensionality reduction using t-Distributed Stochastic Neighbor Embedding (van der Maaten, 2008)
- These state space projections can be used to identify clusters of similar, recurring activity patterns, without the need to define task-related tuning models for individual

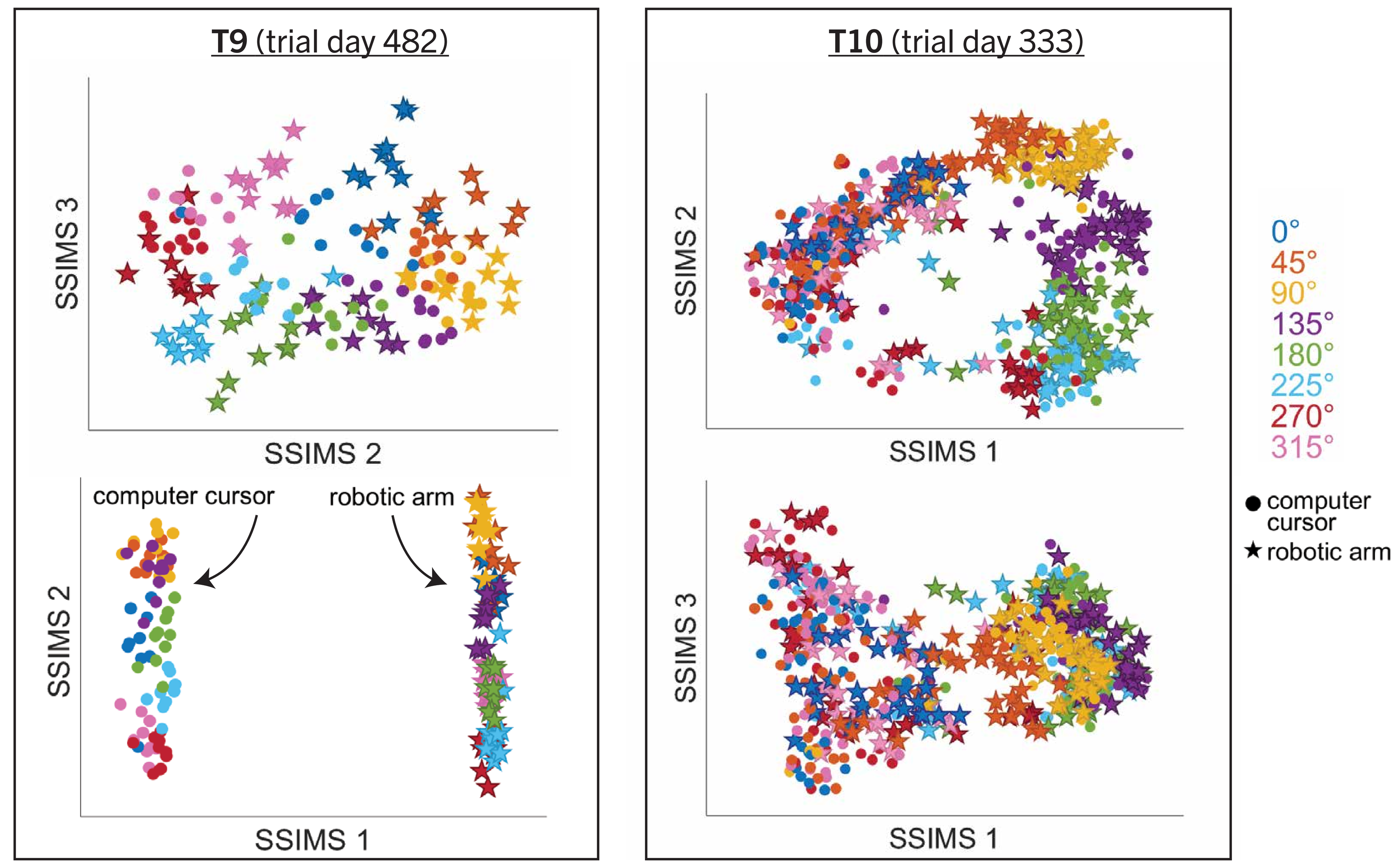


Victor and Purpura, 2011

## RESULTS: END-EFFECTORS COMPARISON

### Engaging different effectors elicits different neural activity patterns

- each point repersents one trial; use spike trains 2.5s before target is acquired
- 10-fold cross validated KNN (K=3) accuracy averaged across all sessions:
  direction classification - T9 : 63.52 ± 9.20% and T10 : 43.57 ± 7.63%
  effector classification - T9 : 97.58 ± 1.55% and T10 : 87.94 ± 5.17%




3D SSIMS spaces of a session of T9 and T10 viewing from 2 orientations. One presents the clustering between directions, while another shows separation of tasks using different effectors.

## CONCLUSIONS & FUTURE WORK

- State space models based on intrinsic activity pattern similarity can be used to:
  (1) detect context-dependent changes in volitional state across daily activities
  (2) differentiate between the intention to engage different effectors (cursor vs. robot)
- Motor cortex contains information about volitional states, in addition to intended movements.
- Future work includes
  - comparing various dimensionality reduction techniques;
  - investigating non-stationarity across days, obtaining more than one day of continuous data;
  - using these data to support the development of a highly interactive BCI system that enables continuous, multi-effector use for people with tetraplegia.

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