BMI Control of a Therapeutic Exoskeleton to Facilitate Personalized Robotic Rehabilitation of the Upper Limb

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Motivation

- **4M stroke survivors** require physical therapy that is labor intensive, highly repetitive at an annual cost of $43 billion
- **Intensive** and **repetitive movement** training achievable with robotics may be **more effective** than traditional approaches
- **Detecting motor intent** using scalp EEG enables "patient-in-the-loop" robotic therapies to **encourage active user engagement** and **cortical plasticity**, potentially maximizing therapeutic benefits

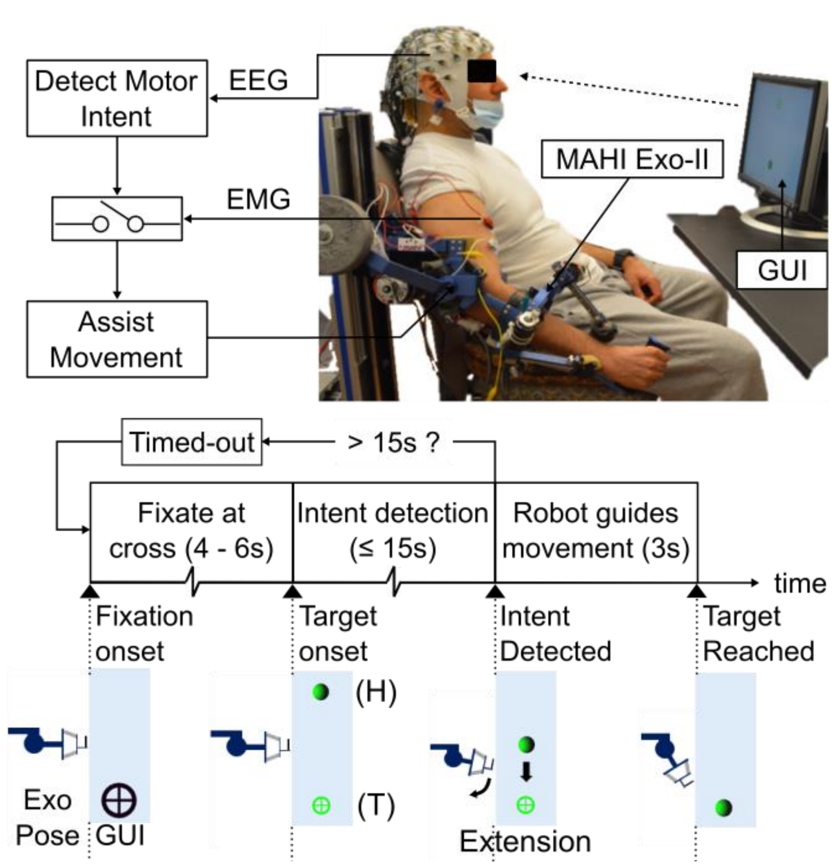
Objective

To accelerate the development, efficacy and use of **robotic rehabilitation** after stroke by capitalizing on the benefits of **subject intent** and **real-time assessment** of impairment

Clinical Study

Experiment Setup

EEG-based closed-loop BMI control of MAHI Exo-II



- The MAHI Exo-II exoskeleton for upper limb rehabilitation supports 4 DOF:
  - Elbow flexion-extension
  - Forearm pronation-supination
  - Wrist flexion-extension
  - Radial-ulnar deviation
- Three control modes for calibration and training:
  - User-driven (motors unpowered)
  - User-triggered (velocity triggering to activate robot guidance)

Protocol for Clinical Study

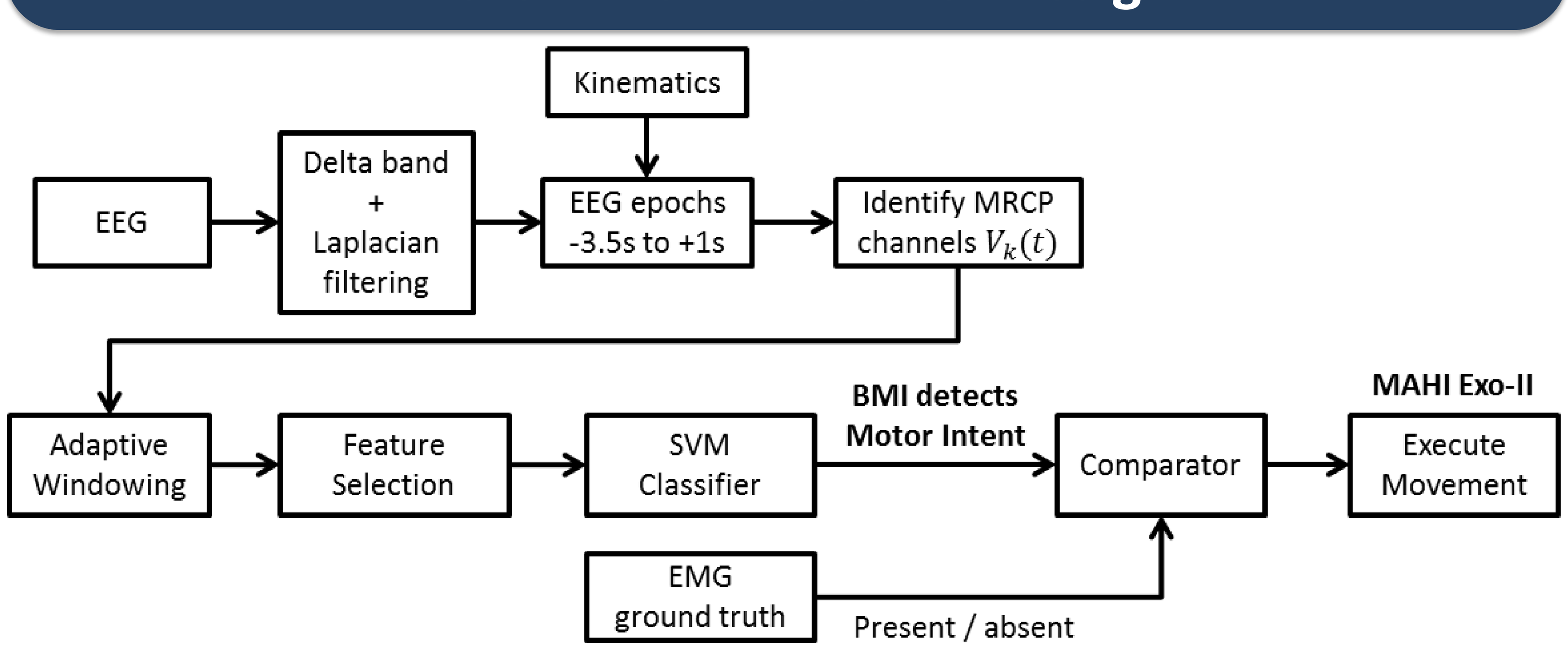
Day 1 → **Day 2** → **Day 3** → → → **Day 14**

- Record EEG data in Triggered and Backdrive modes
- Train EEG classifier

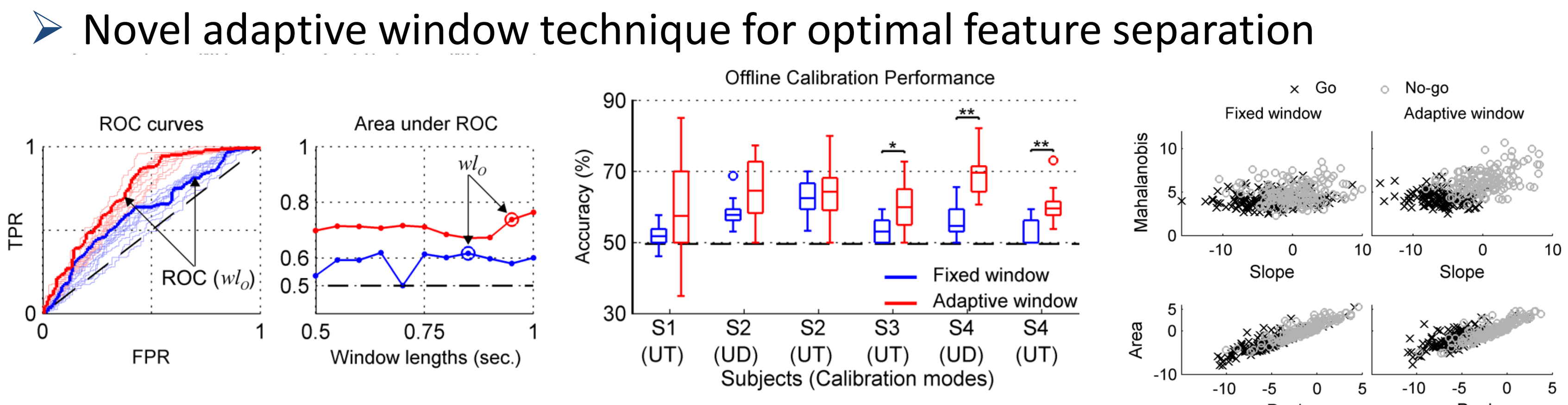
- Closed-loop testing of BMI control
- Data collection in blocks of 20 trials

Calibration ⟷ **Closed-Loop Control**

Motor Intent Classifier Design



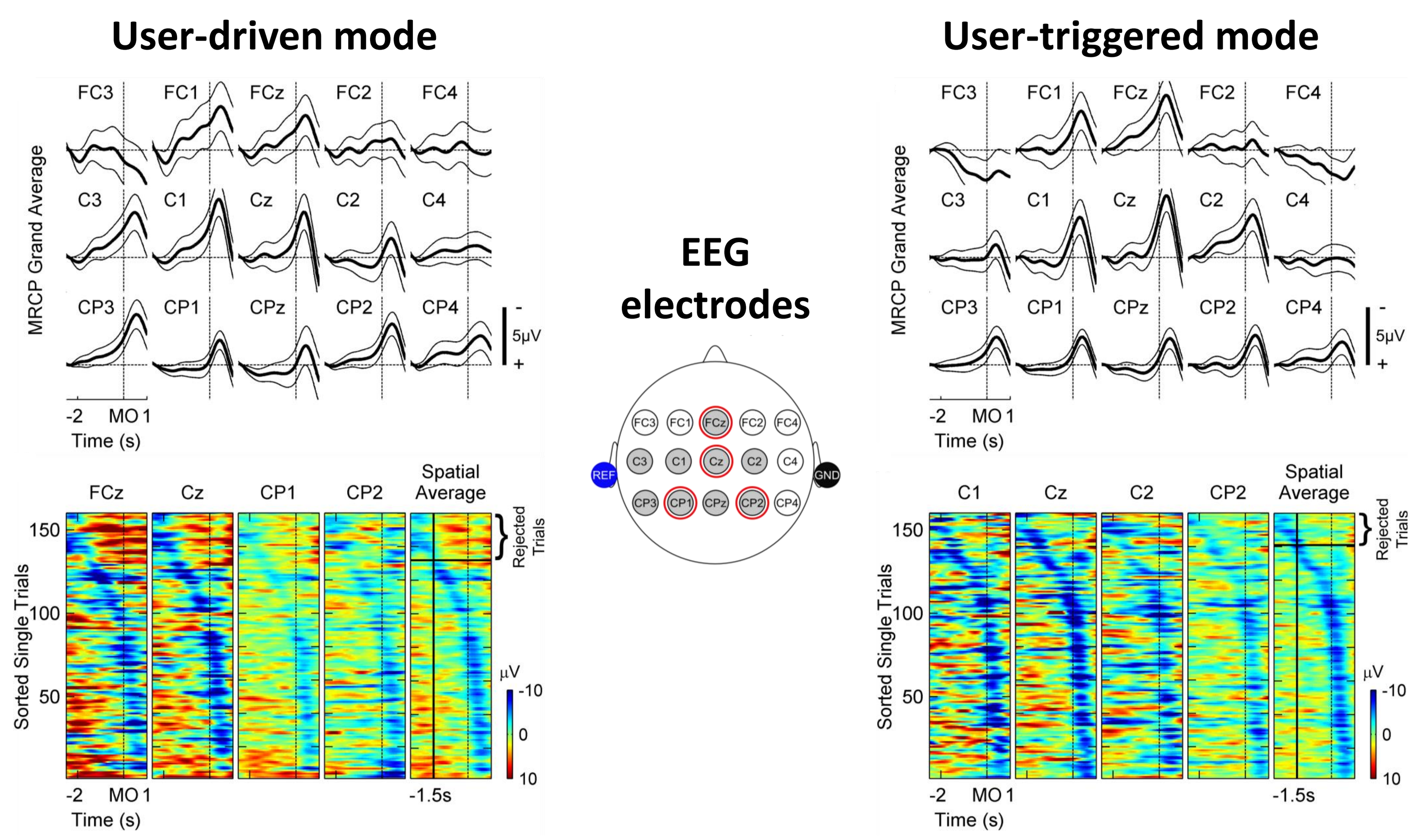
- Novel adaptive window technique for optimal feature separation



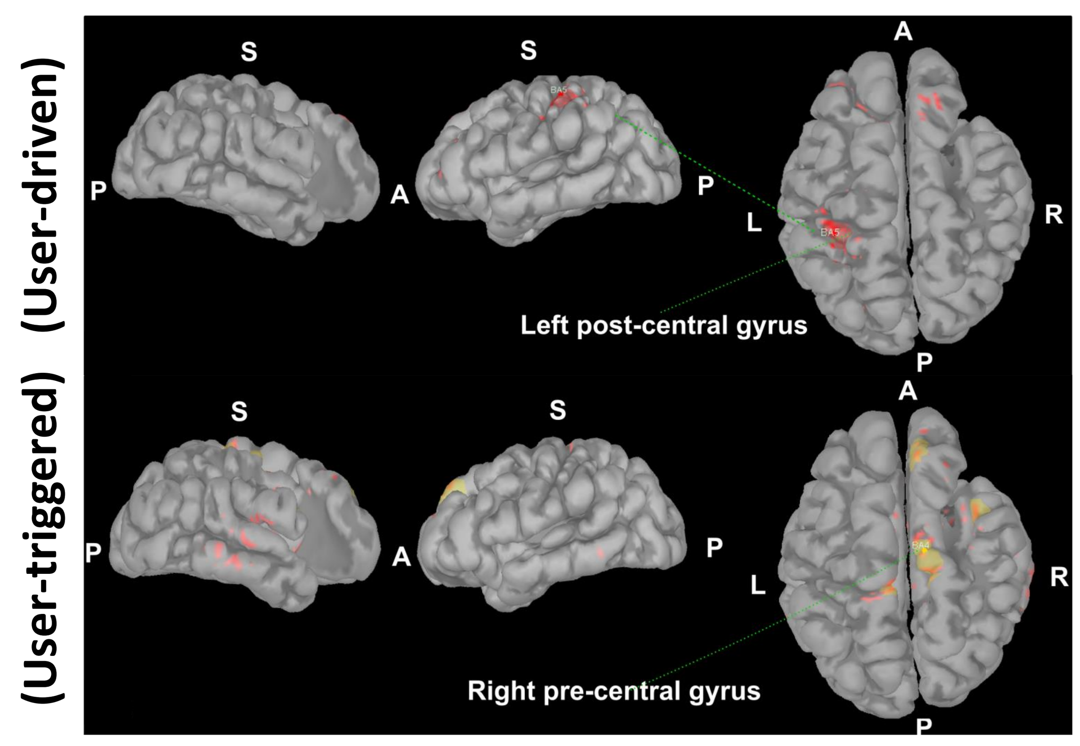
Results

Results from feasibility study (exemplified for a single subject)

- Motor intent detected during different exoskeleton training modes



Source Localization of Motor Intent

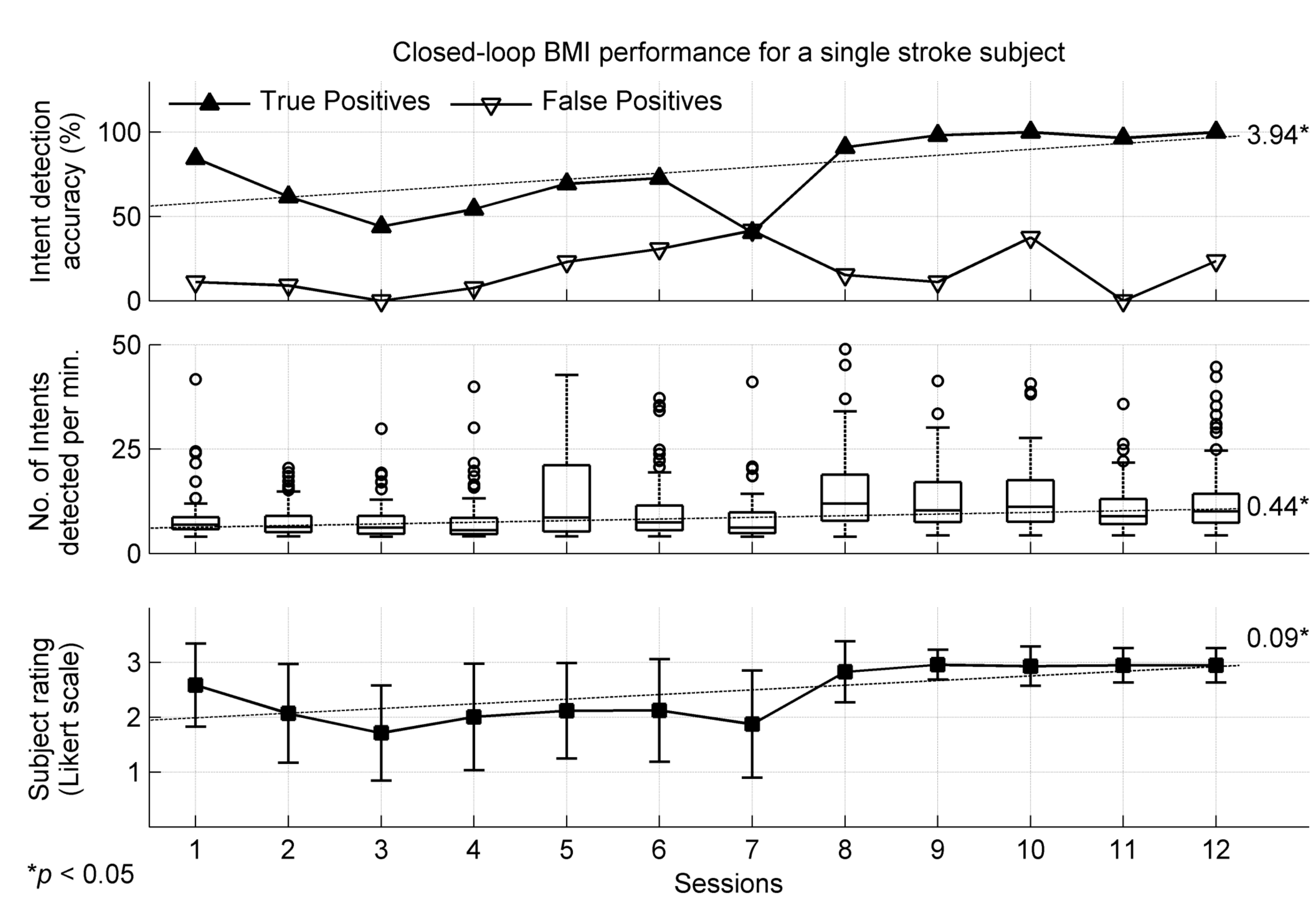


Significant activations from t-statistic ($p < 0.05$) are shown on the cortex

Different activation regions can be due to difference in BMI calibration, i.e. user-driven vs. user-triggered modes

Distributed current source maps (weighted MNE) at time points associated with motor intent for the group averaged trials

Preliminary Results from Ongoing Clinical Study



Future Work

- Conduct **longitudinal study** to evaluate effectiveness of **BMI-Robot therapy** in stroke subjects by monitoring functional recovery, movement coordination, and neuroplastic changes
- Expand the degrees of control by classifying **movement direction** and **reconstructing joint kinematics** from EEG

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