A classifier for improving cause and effect in SSVEP-based BCIs for individuals with complex communication disorders

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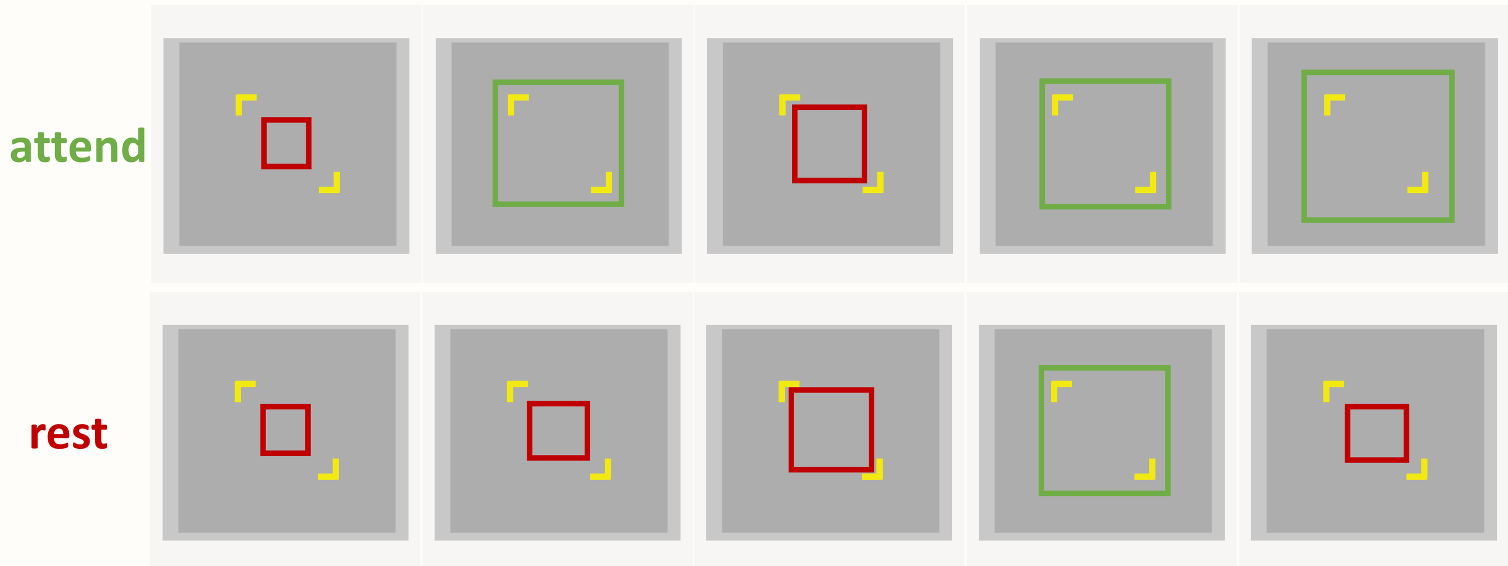
Introduction

- Helping people with complex communication disorders (CCDs) communicate requires establishing cause and effect between the assistive technologies and their users
- Steady-state visual evoked potentials (SSVEP)-based brain-computer interfaces (BCIs) can help us achieve this goal
- We present the cumulative sum canonical correlation analysis ($\text{CCA}_{\text{CUSUM}}$) classifier to improve the cause-and-effect relationship between a user's behavior and the SSVEP-based BCI

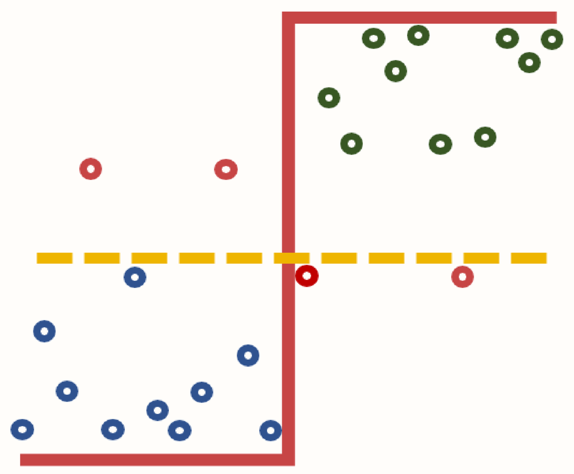
Methods: MusicBox

- **MusicBox***:* simple SSVEP-based BCI to help establish cause and effect for CCD individuals
- user can attend to a flickering stimulus (attend state) or be at rest (rest state)
- provides auditory feedback if user is in attend state by *playing music*



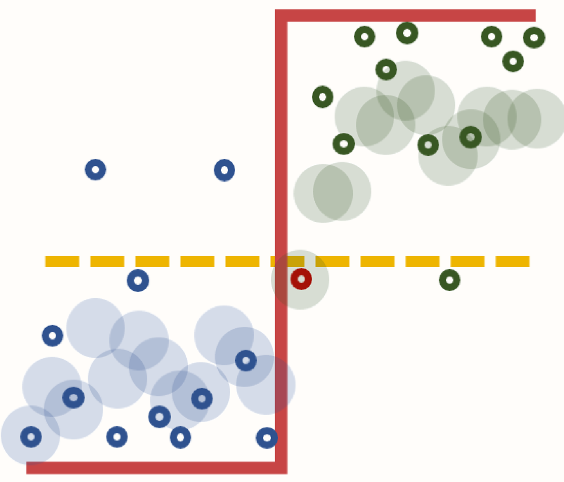
Methods: Conventional Approach

- **Conventional Approach:** compares samples with fixed threshold to identify whether a user is in attend or rest state
- Feature extraction based on canonical correlation analysis (CCA)
- Discard Context → Potential information loss



$\text{CCA}_{\text{CUSUM}}$

- **$\text{CCA}_{\text{CUSUM}}$**: identifies states by detecting transitions between them
- Use **$\text{CCA}_{\text{CUSUM}}$** with sliding window to extract features from EEG signals
- **Assumption:** normal distribution with parameters $\theta_0 = (\mu_0, \sigma)$ and $\theta_1 = (\mu_1, \sigma)$ before/ after change

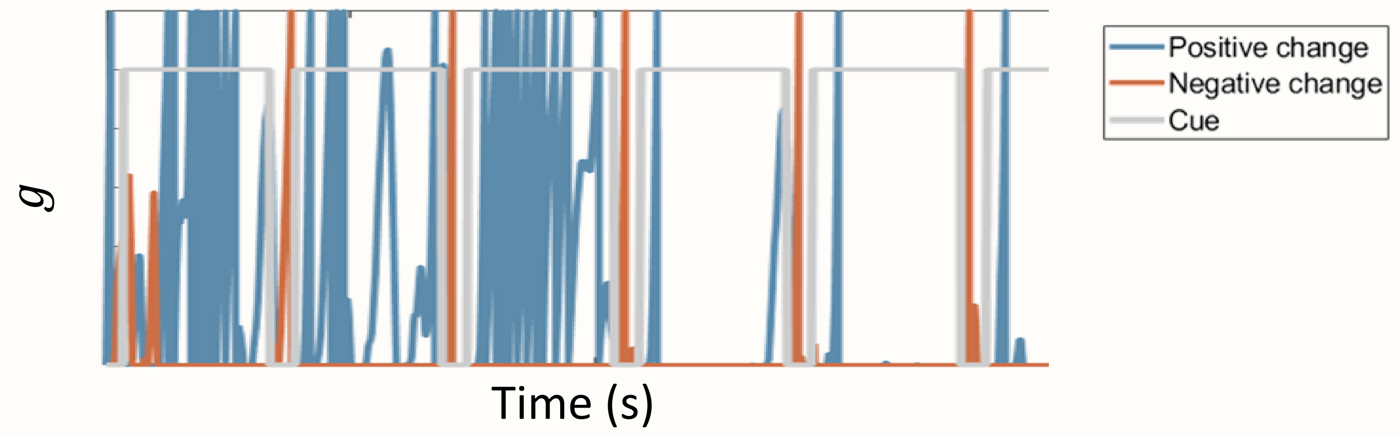


$\text{CCA}_{\text{CUSUM}}$

- Using hypothesis testing, we obtain two different tests:

$$g_i^+ = \max\left(g_{i-1}^+ + r_i - \mu_0 - \frac{\upsilon}{2}, 0\right) \geq h$$
$$g_i^- = \max\left(g_{i-1}^- - r_i + \mu_0 - \frac{\upsilon}{2}, 0\right) \geq h$$

- r_i: canonical correlation of i^{th} sliding window
- $\upsilon = |\mu_1 - \mu_2|$: magnitude of change
- h: fixed threshold
- g_i^+ detects positive changes
- g_i^- detects negative changes
- Learn online model parameters μ_0 and υ



Performance Metric

- **Proposed metric M**: measure cause-and-effect relationship between MusicBox and user's behavior

$$\text{EPOR} = \frac{1}{l_{\text{ON}}} \times E\left[m \middle| \begin{matrix} r_k \text{ correctly classified as positive} \\ \forall k \in \{i+1, \dots i+m\} \end{matrix}\right]$$

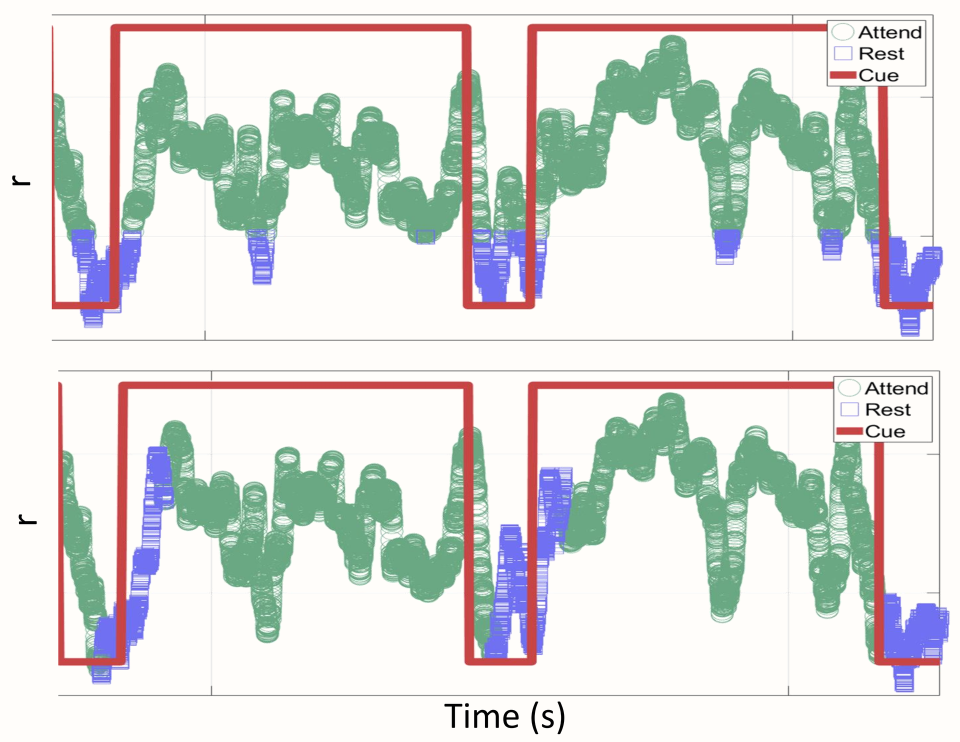
$$\text{ENOR} = \frac{1}{l_{\text{OFF}}} \times E\left[m \middle| \begin{matrix} r_k \text{ correctly classified as negative} \\ \forall k \in \{i+1, \dots i+m\} \end{matrix}\right]$$

$$M = \frac{2 \times \text{EPOR} \times \text{ENOR}}{\text{EPOR} + \text{ENRO}}$$

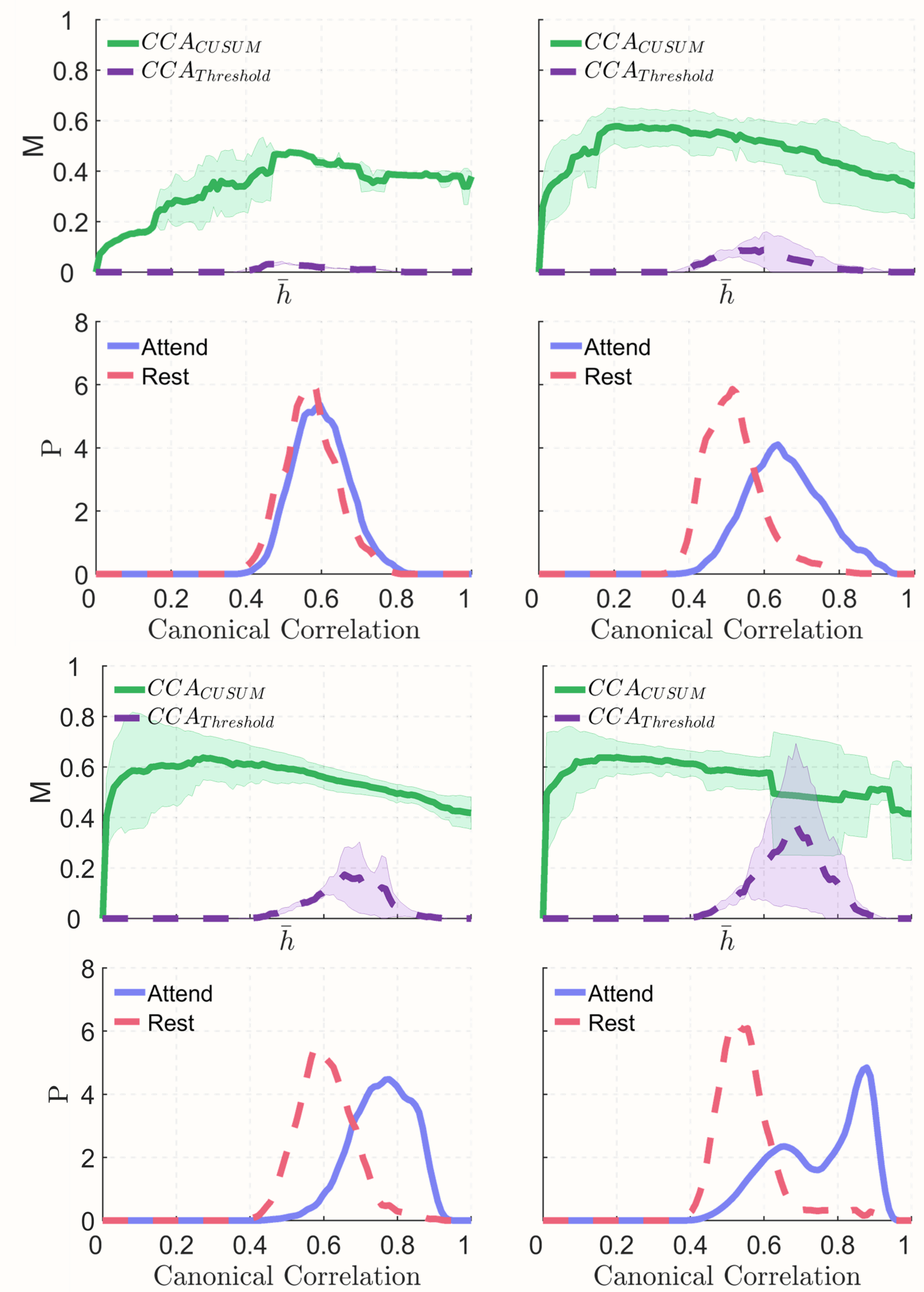
- l_{ON} / l_{OFF}: length of intervals where the participant was in attend/rest state

Data and Results

- (right) Conventional method vs $\text{CCA}_{\text{CUSUM}}$ in a single trial experiment
- Four participants with no CCD
- Eight EEG channels
- Multiple trials per participant



Data and Results



(top) Comparing metric '**M**' for $\text{CCA}_{\text{CUSUM}}$ and the conventional method (bottom) The distribution of samples under the two hypotheses

Summary

- $\text{CCA}_{\text{CUSUM}}$: Using change detection to improve cause and effect in BCIs
- We evaluated $\text{CCA}_{\text{CUSUM}}$ using MusicBox, an SSVEP-based BCI
- $\text{CCA}_{\text{CUSUM}}$ improved cause and effect when samples were less separable

Funding

The National Center for Adaptive Neurotechnologies is supported by the National Institute of Biomedical Imaging and Bioengineering of the NIH P41 EB018783-07 (JRWolpaw).
References are available upon request.

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