A Classifier for Improving Cause and Effect in SSVEP-based BCIs for Individuals with Complex Communication Disorders

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Outline

A classifier for improving cause and effect in SSVEP-based BCIs

1 Introduction

- ➢ Cause and effect
- ➢ MusicBox
- ➢ EEG/SSVEP
- ➢ Feature extraction

3 Performance Metric

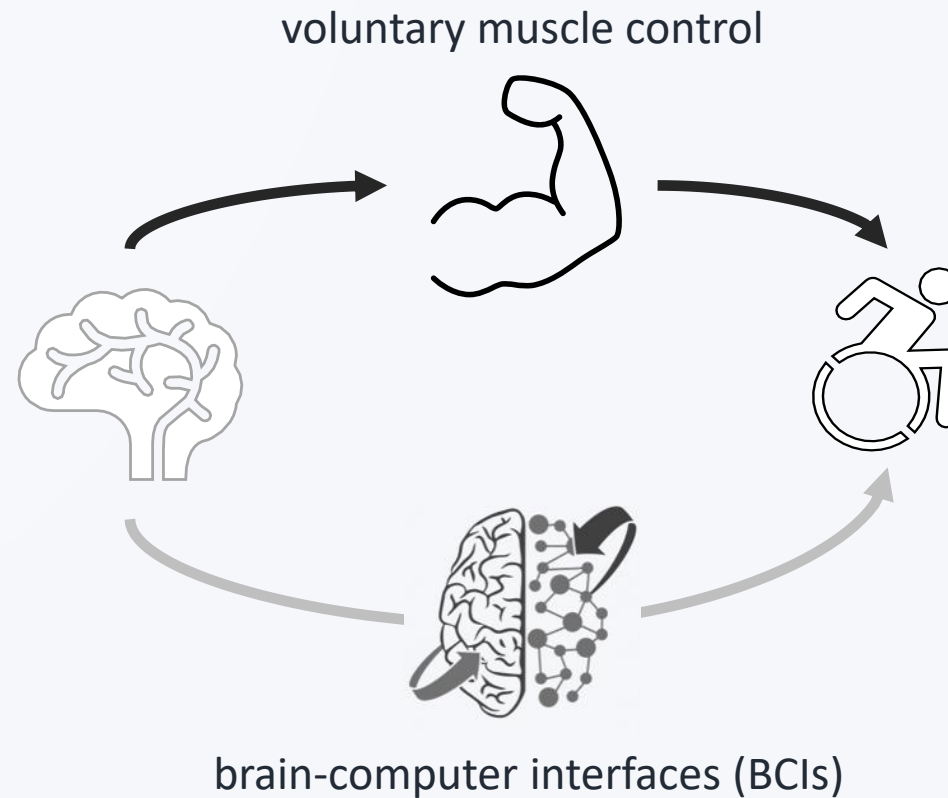- ➢ Challenges
- ➢ Our performance metric

2 CCA_CUSUM

- ➢ Conventional approach
- ➢ Challenges
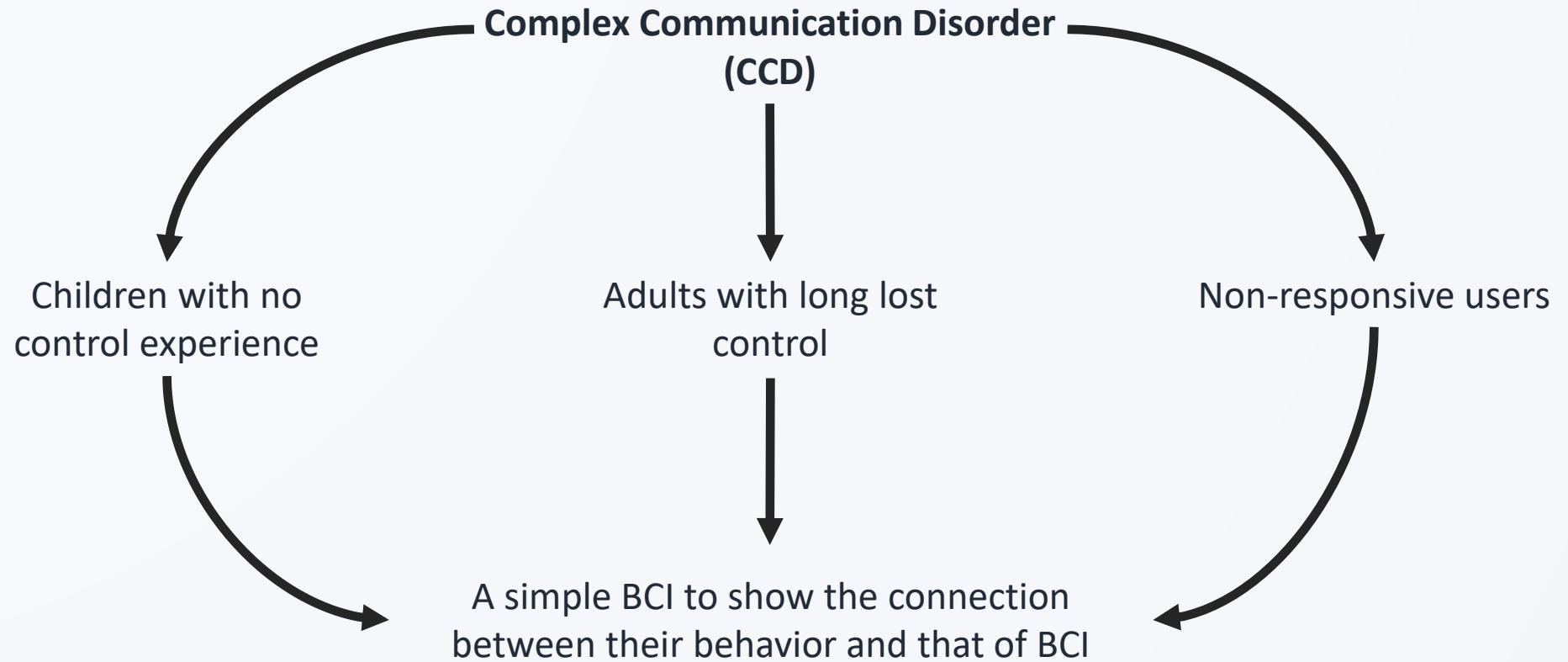- ➢ Our approach
- ➢ Formulation
- ➢ Demo

4 Results

- ➢ Single case example
- ➢ Overall results
- ➢ Future work

Brain-Computer Interfaces (BCIs)

voluntary muscle control

brain-computer interfaces (BCIs)

Our goal: Improving cause-and-effect relationship between BCIs and their users' behaviors
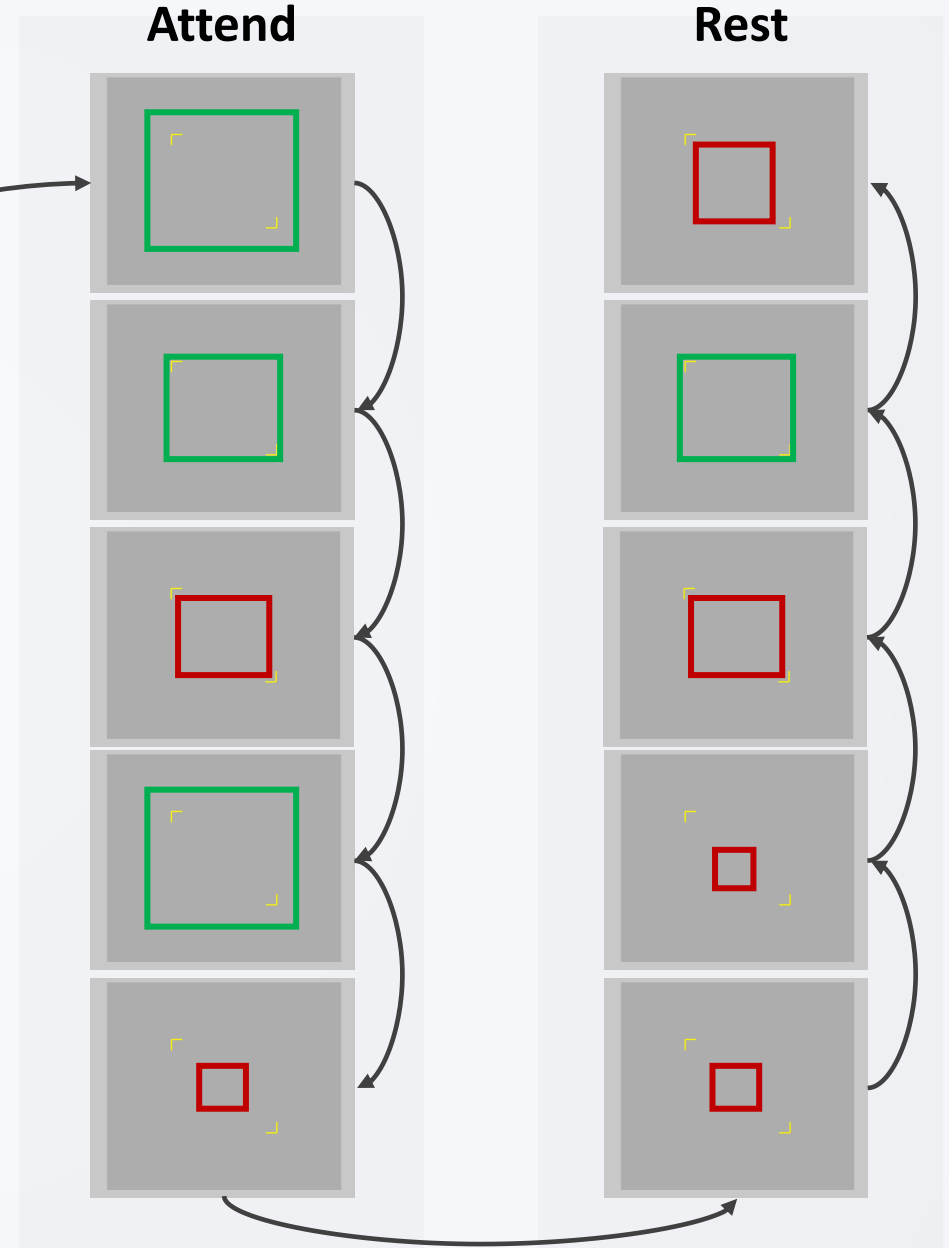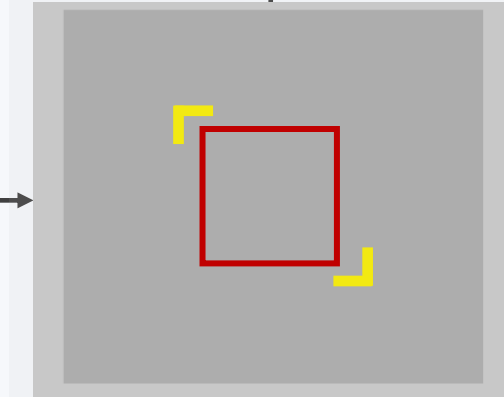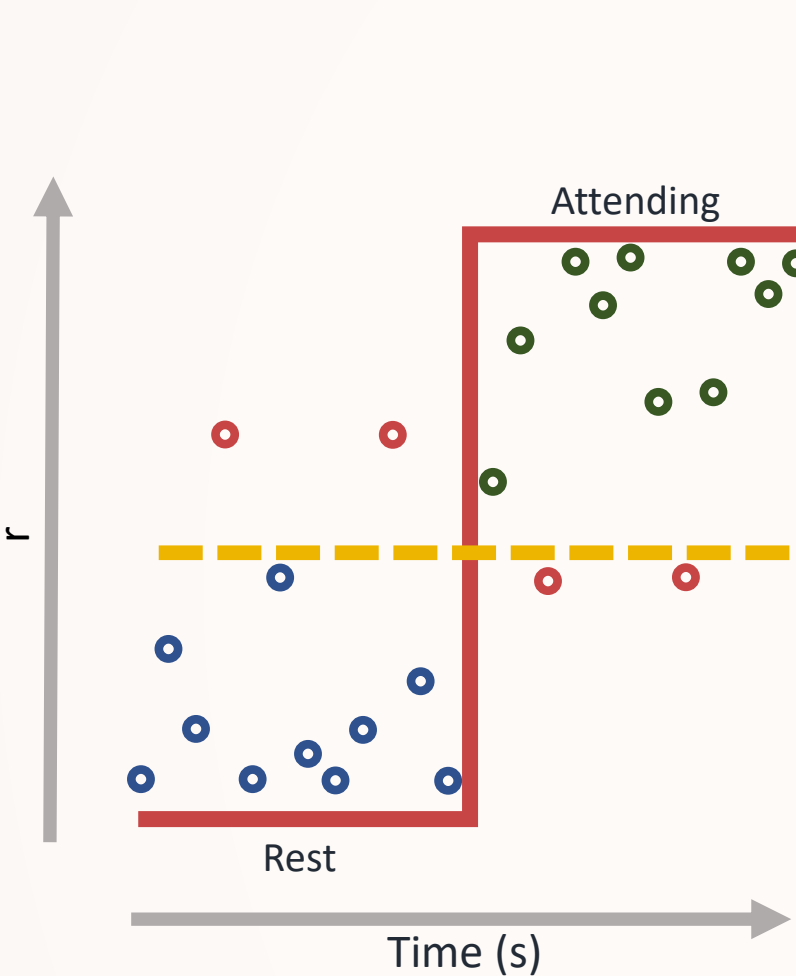
Cause and effect

MusicBox

Steady-state visual evoked potential (SSVEP)

Canonical correlation analysis (CCA)

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Classification

Positive Change
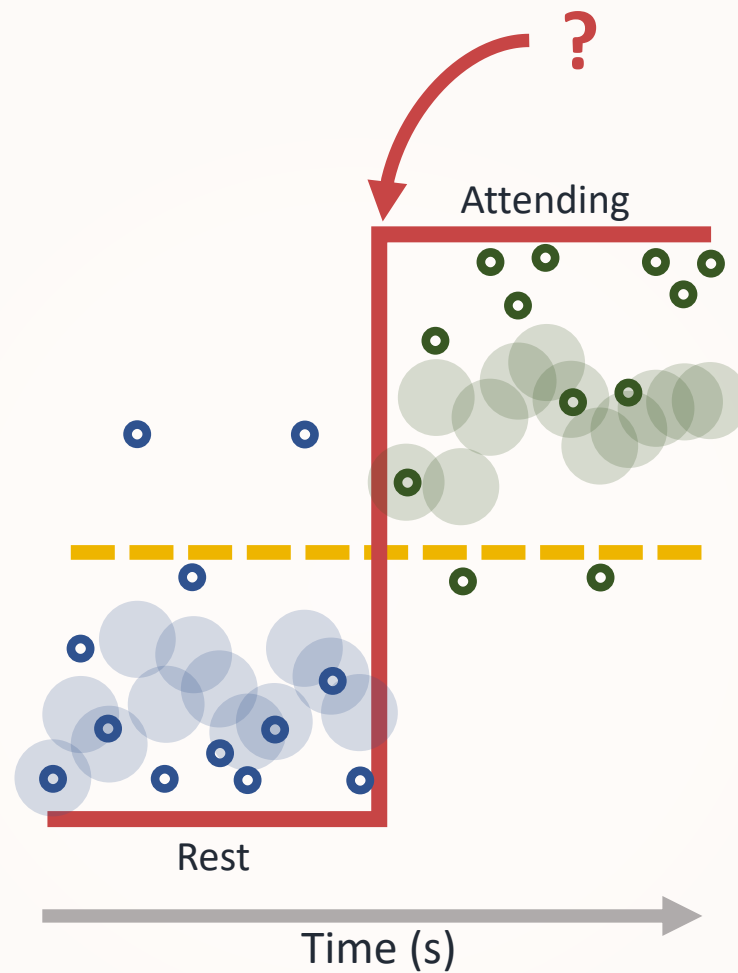
Negative Change

H_0: Data Distribution before change
H_1: Data Distribution after change
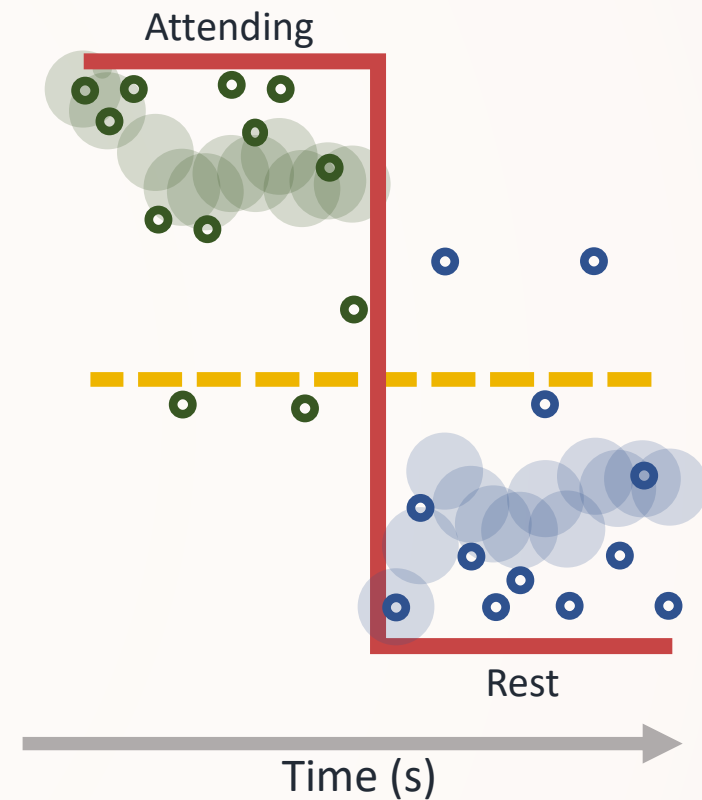
CCA_{CUSUM}

$$\Lambda = \log \frac{\mathrm{p}(r|H_0)}{p(r|H_1)} = \log p(r|\mathcal{M}, \theta_0) - \log p(r|\mathcal{M}, \theta_1)$$

Normal distribution
IID samples

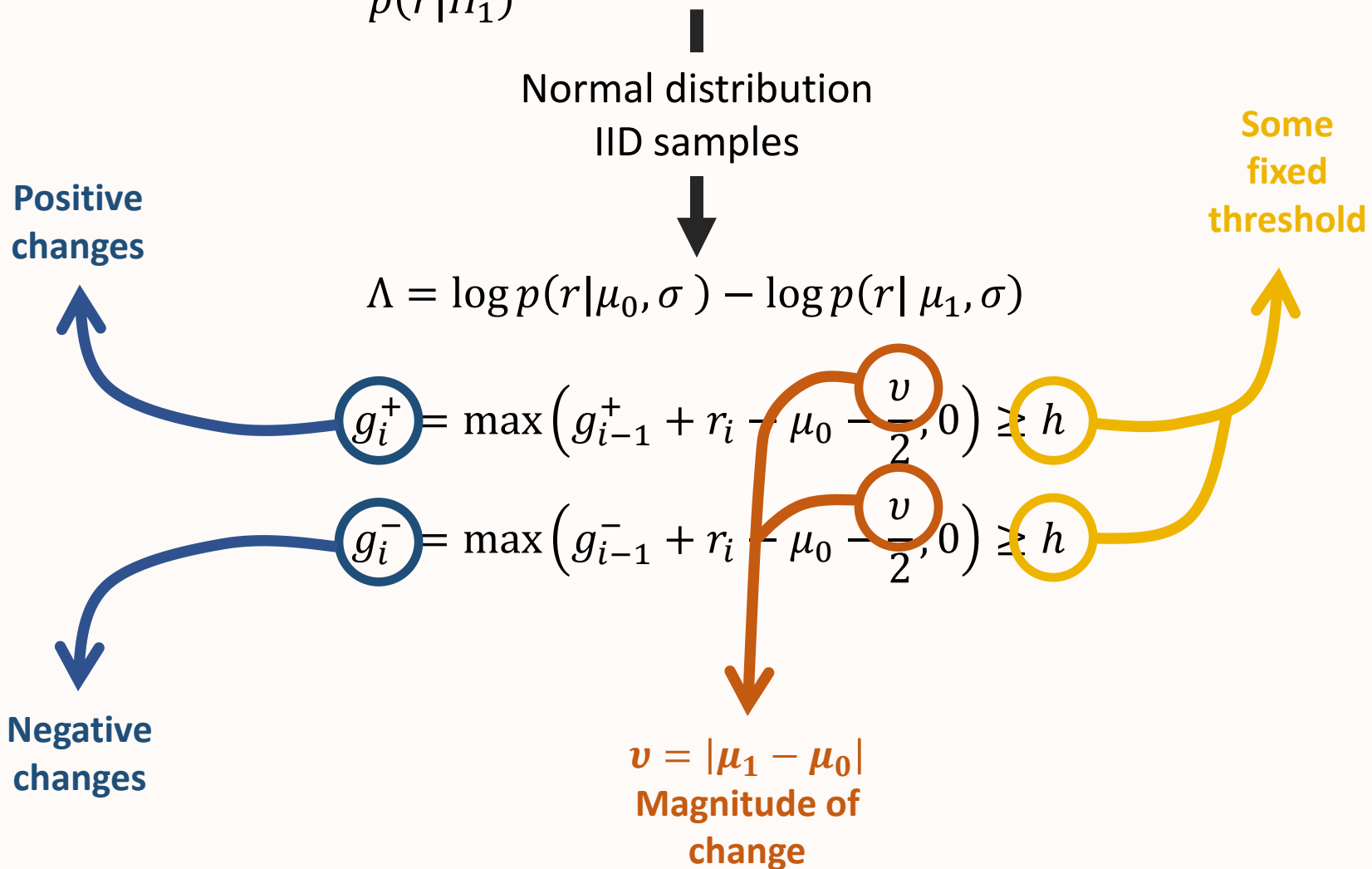$$\Lambda = \log p(r|\mu_0, \sigma) - \log p(r|\mu_1, \sigma)$$

Positive changes

Some fixed threshold

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

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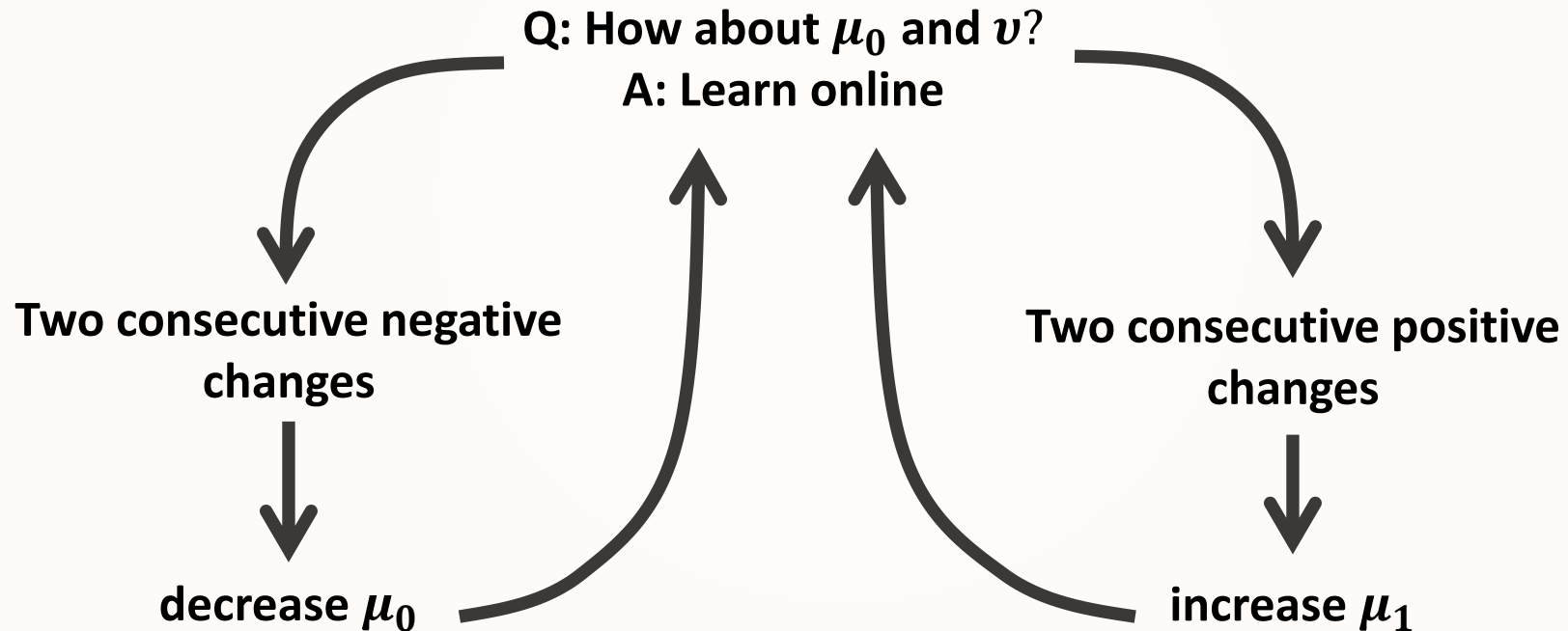
Negative changes

$$\boldsymbol{v = |\mu_1 - \mu_0|}$$
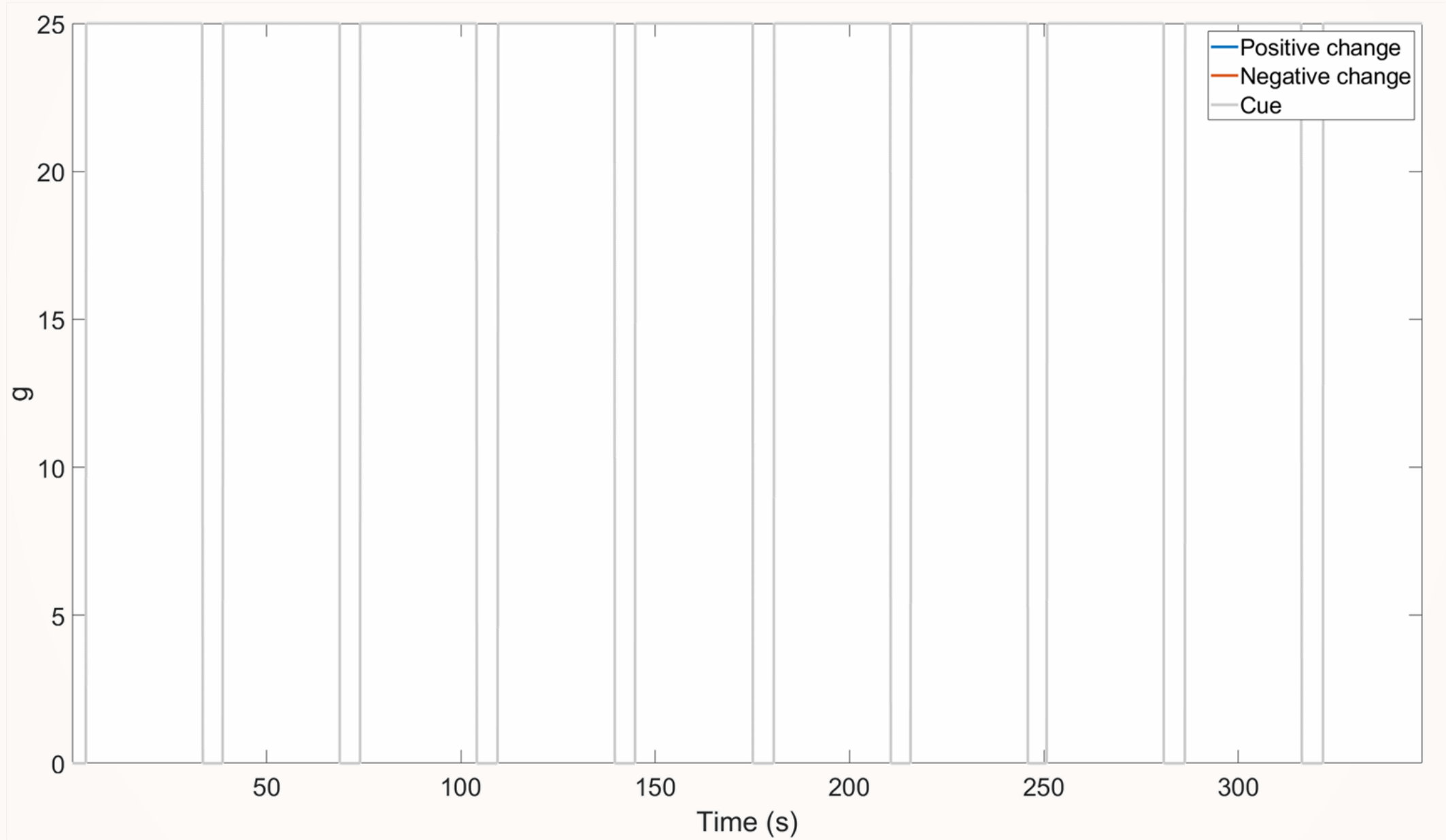**Magnitude of change**

Parameter Estimation

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

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

Q: How about μ_0 and v?
A: Learn online

Two consecutive negative changes

Two consecutive positive changes

decrease μ_0

increase μ_1

Online Learning

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Performance Metric

$$\text{EPO}_j = E\left[m\,\middle|\,\begin{matrix} r_k^j \text{ correctly classified as positive} \\ \forall k \in \{i+1, \ldots, i+m\} \end{matrix}\right]$$

$$\text{ENO}_j = E\left[m\,\middle|\,\begin{matrix} r_k^j \text{ correctly classified as negative} \\ \forall k \in \{i+1, \ldots, i+m\} \end{matrix}\right]$$

$$\text{EPOR}_j = \frac{\text{EPO}_j}{l_{\text{on}}}, \qquad \text{ENOR}_j = \frac{\text{ENO}_j}{l_{\text{off}}}$$
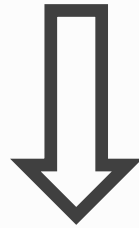
$$M = \frac{2 \times \text{EPOR} \times \text{ENOR}}{\text{EPOR} + \text{ENOR}}$$
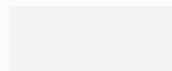
Performance Metric

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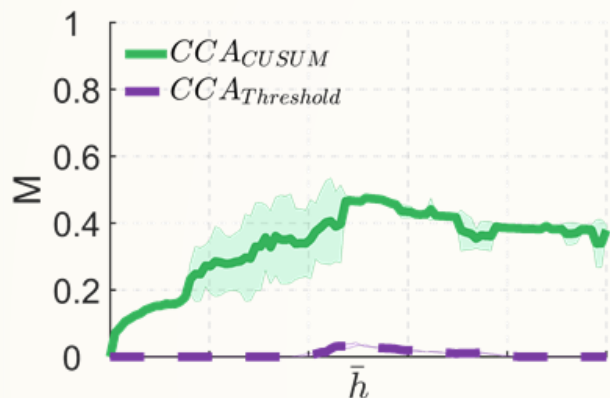- ➢ Our performance metric

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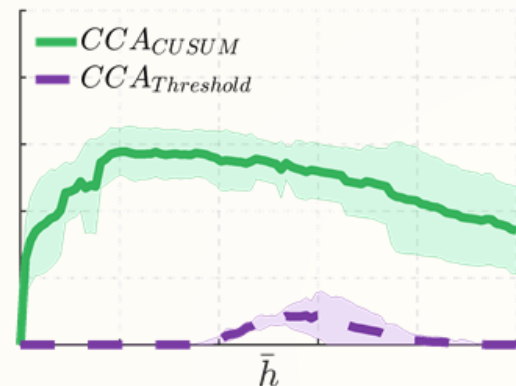- ➢ Our approach
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- ➢ Single case example
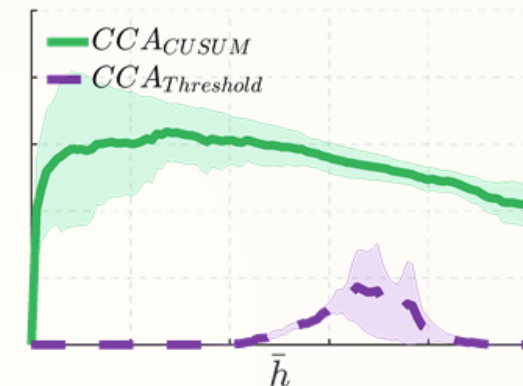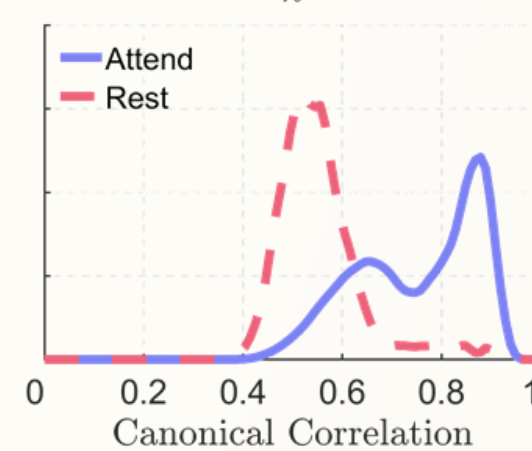- ➢ Overall results
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Results
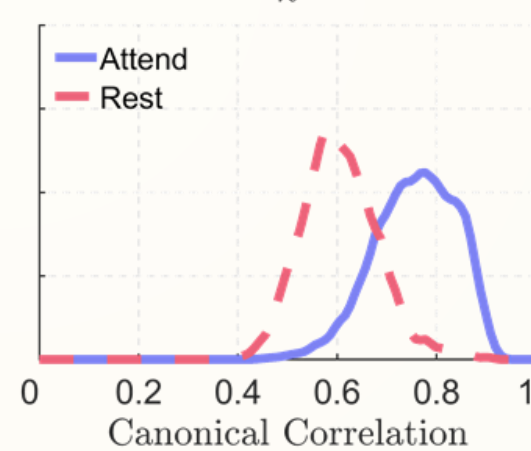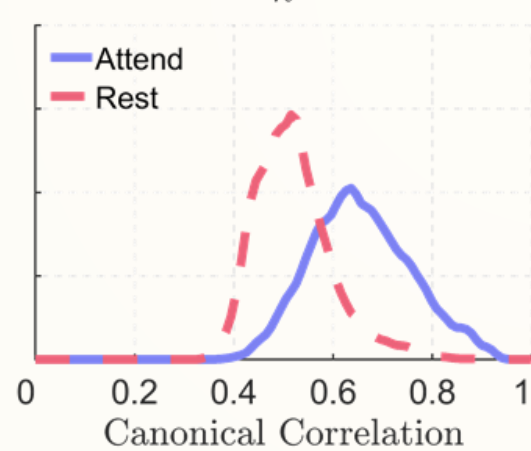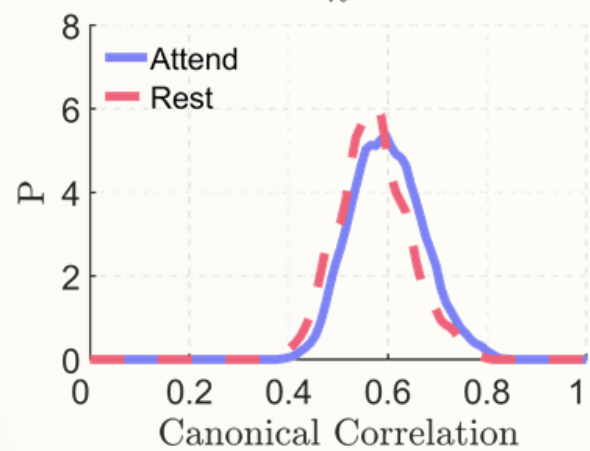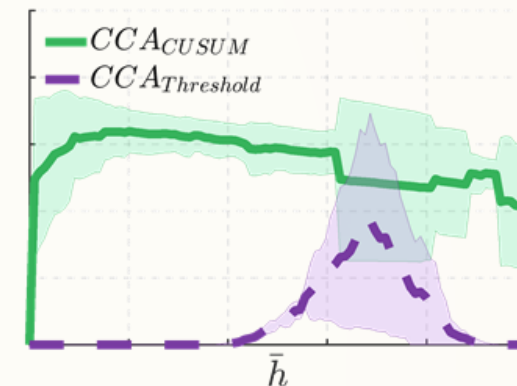
Future Work

➢ Participants with CCDs

➢ Collaborating with Shirley Ryan AbilityLab

➢ A participant with ALS

Thank You!

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