Rapid Adaptation of Brain Reading Interfaces based on Threshold Adjustment

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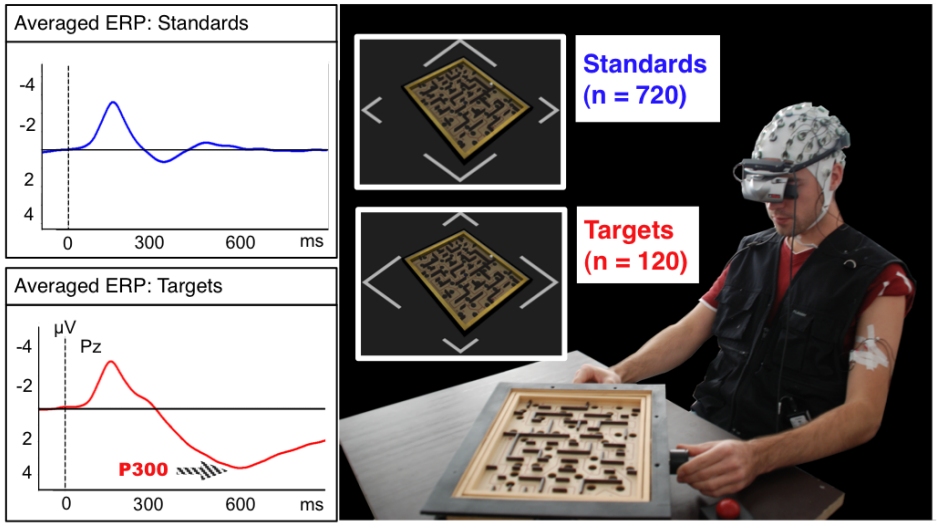

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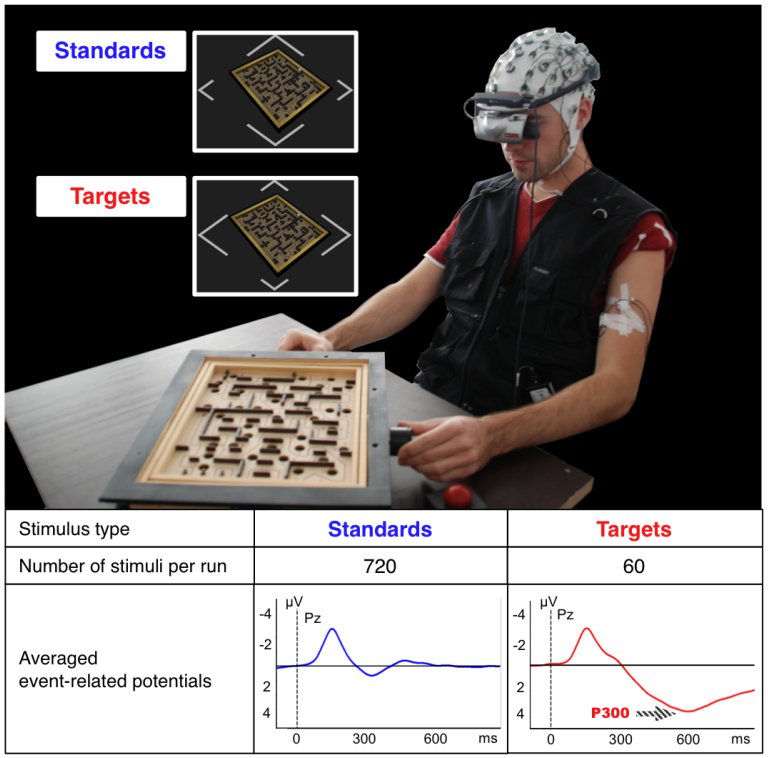
Operator Monitoring in Telemanipluation

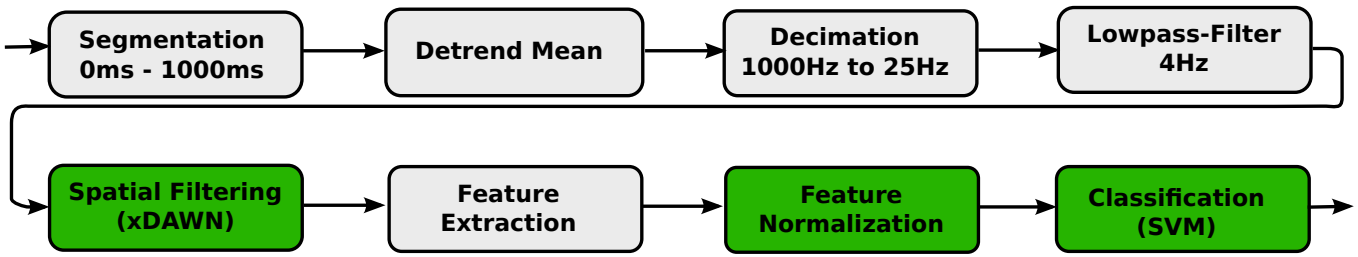
Did the operator get an alert that was presented to him or her?

Real-time detection of the "P300 potential" can answer this question!

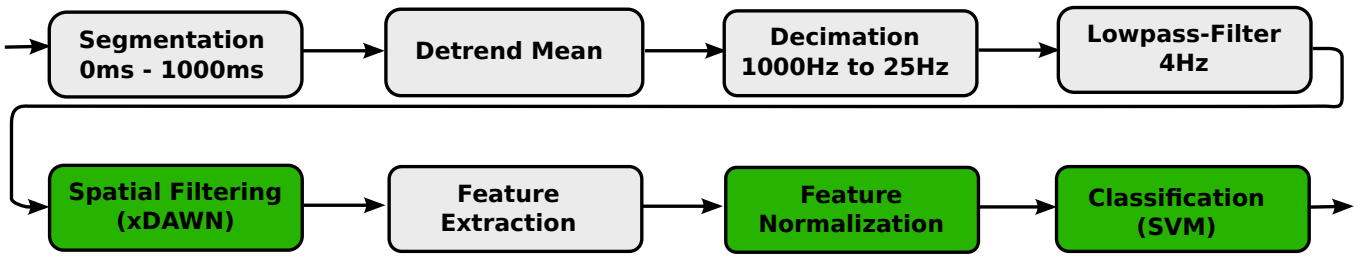


BRIO Oddball paradigm: Experimental setup to evaluate methods for single-trial P300 detection

Machine Learning approach

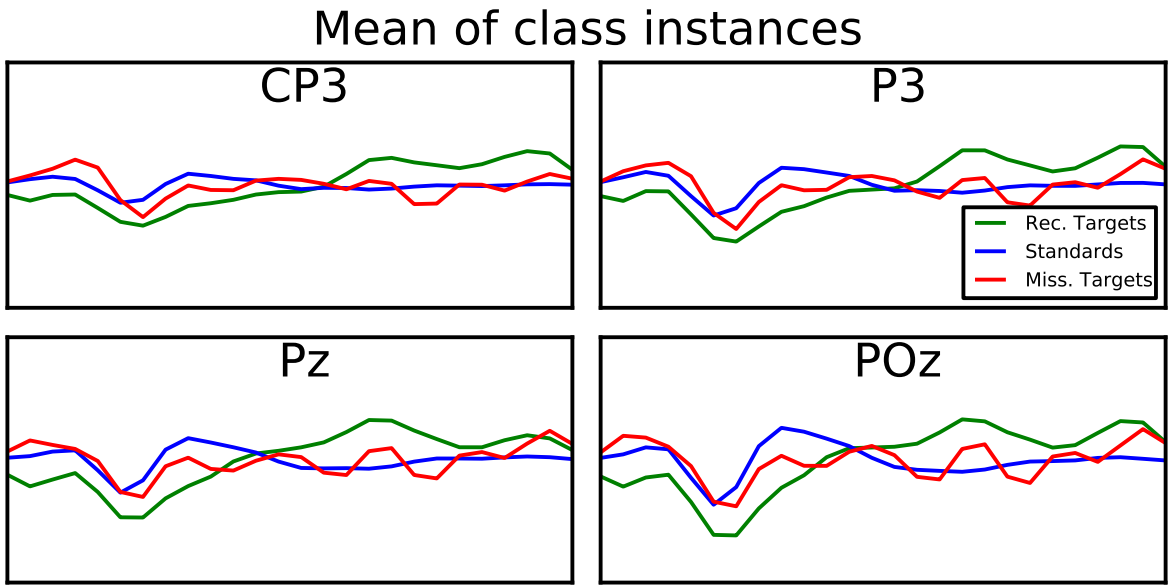


Machine Learning approach



- **Classification task:** Distinguish recognized and missed Target stimuli
- Requires labeled training data acquired during a calibration procedure prior to usage session
- **Challenge:** Frequency of Missed Targets is low and not under the BRI's control

Similarity of classes



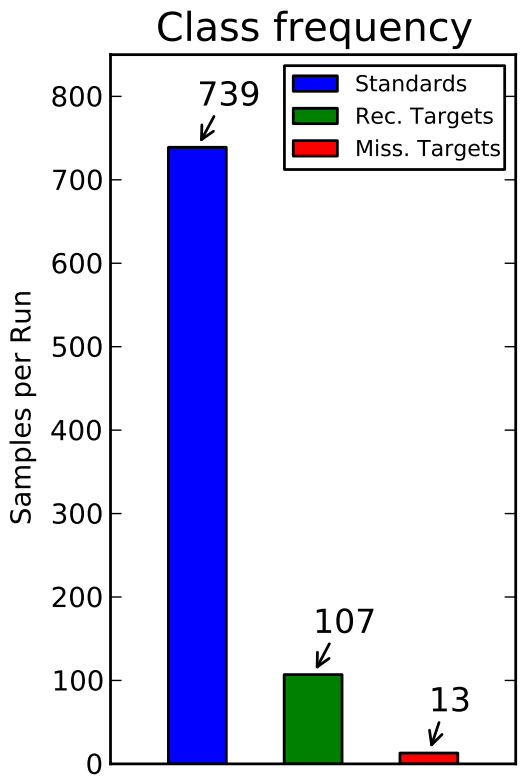
- Mean of Standard class is more similar to Missed Targets than to Recognized Targets
- **Hypothesis:** Instances of Standard class may be used in place of Missed Target instances

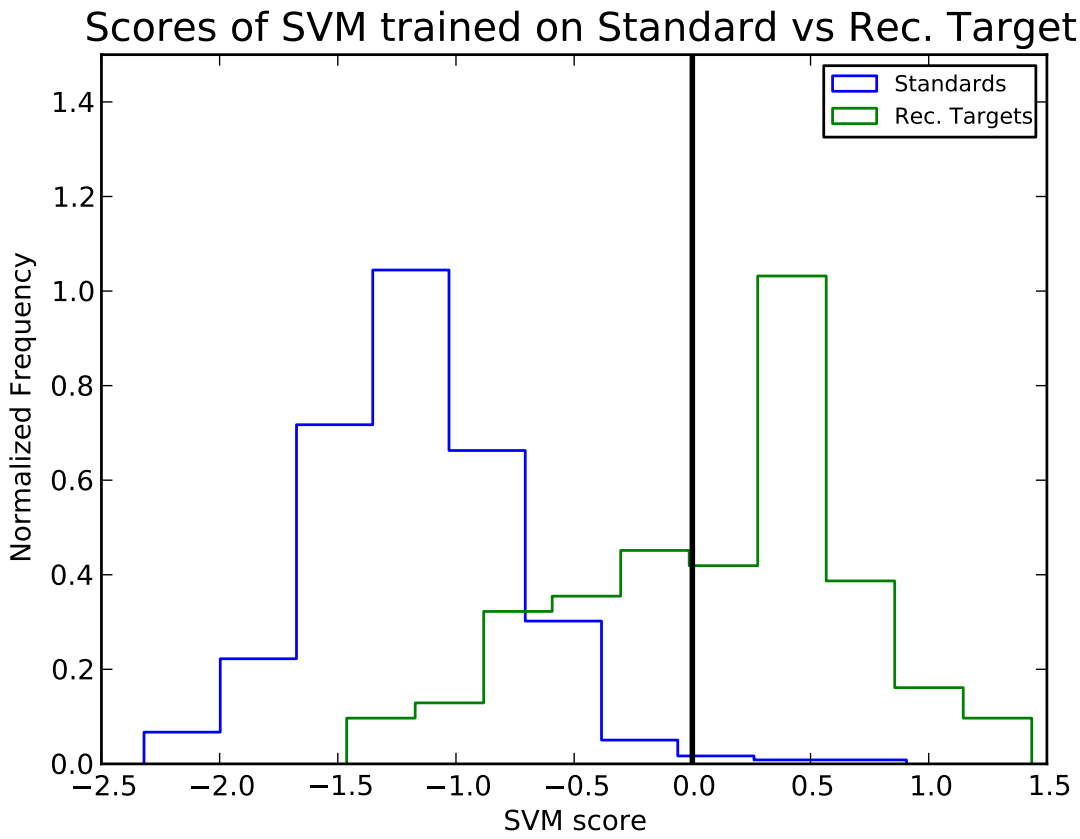
Approach

Two-stage training process:

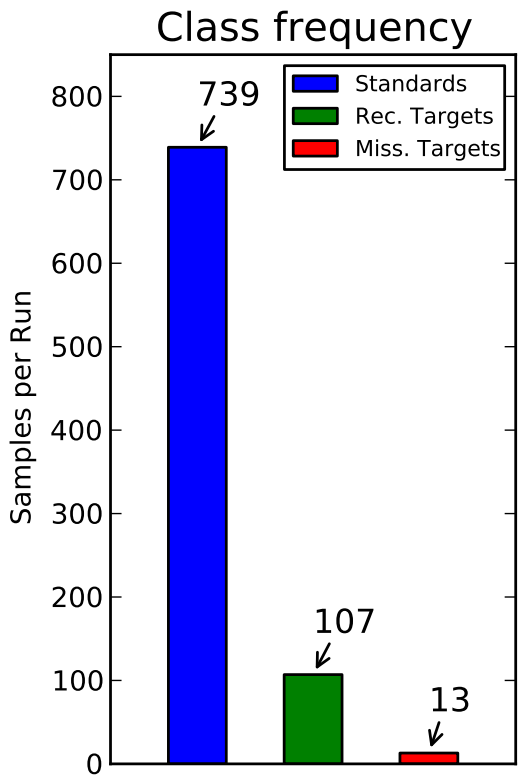
- First stage: Train data flow to distinguish patterns evoked by presentation of Standard and Recognized Target stimuli
- Second stage: Adapt data flow such that it can also distinguish patterns evoked when missing and recognizing Target stimuli
- Second stage should be easier (i.e. require less training data)
- **Approach**: Adjustment of classification threshold

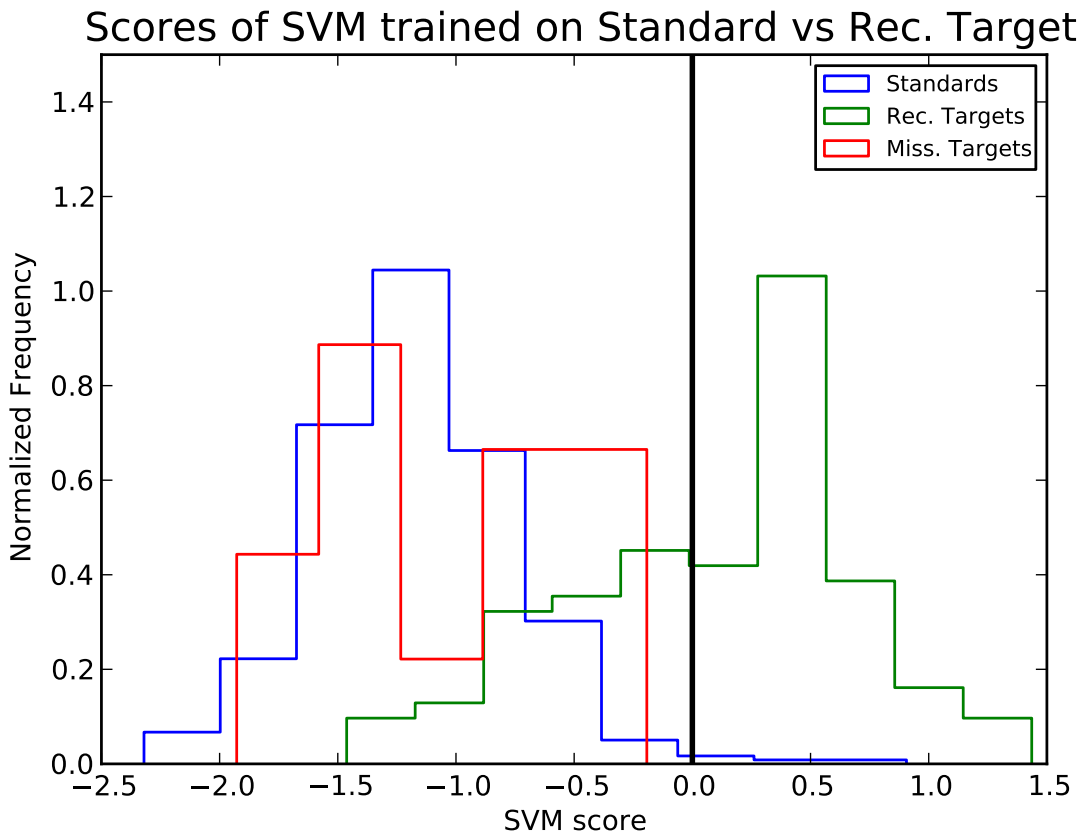
Class frequency and SVM score distribution



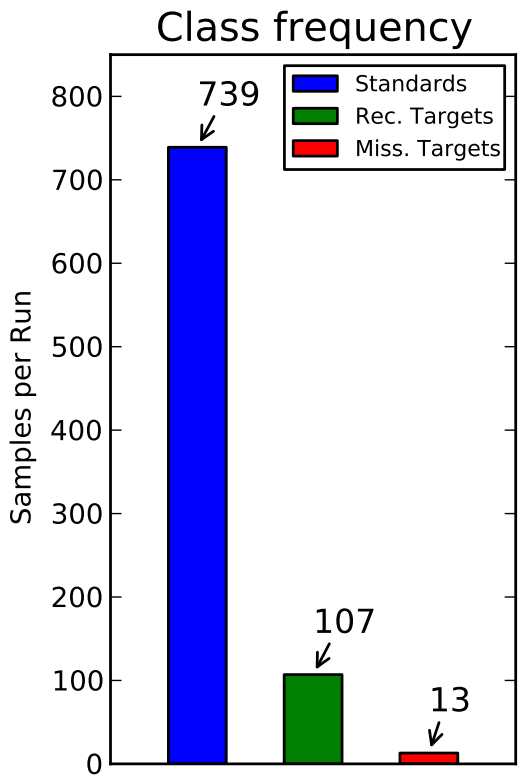


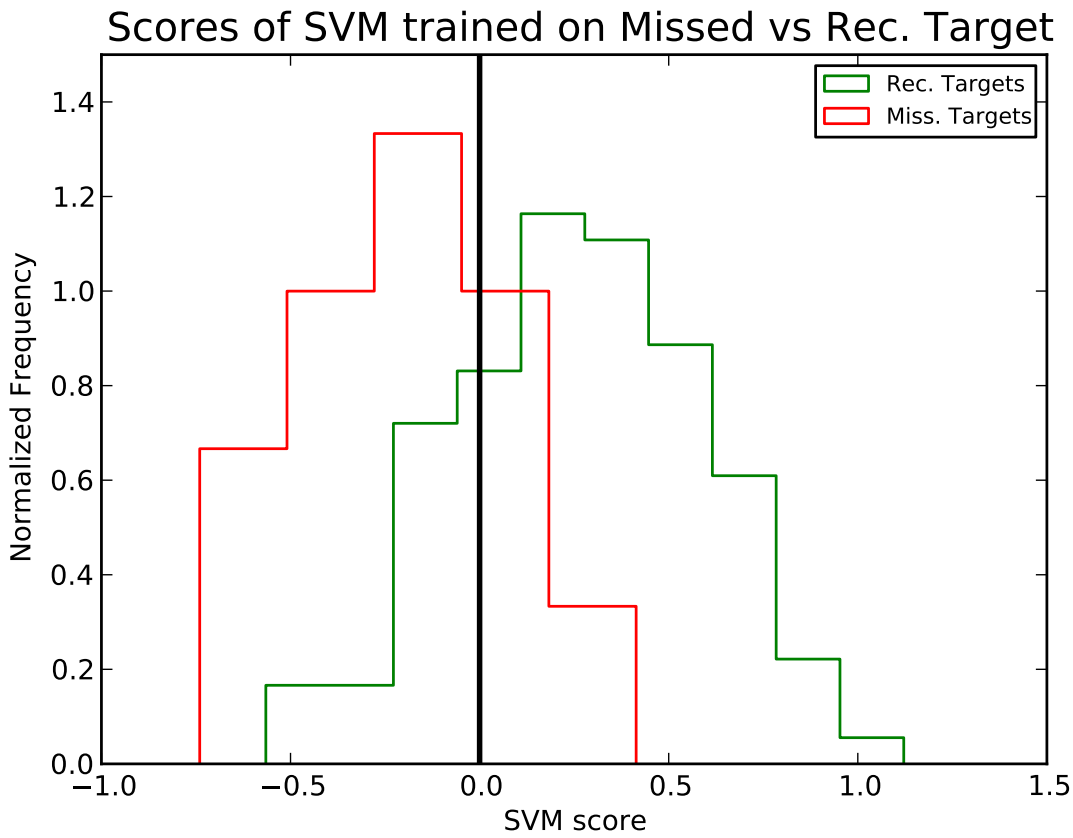
Class frequency and SVM score distribution





Class frequency and SVM score distribution





Adaptation based on SVM threshold adjustment

- SVM decision rule for input x (linear kernel):

$$y = sign(\mathbf{w}^T\mathbf{x} + b + t) \text{ with } t = 0$$

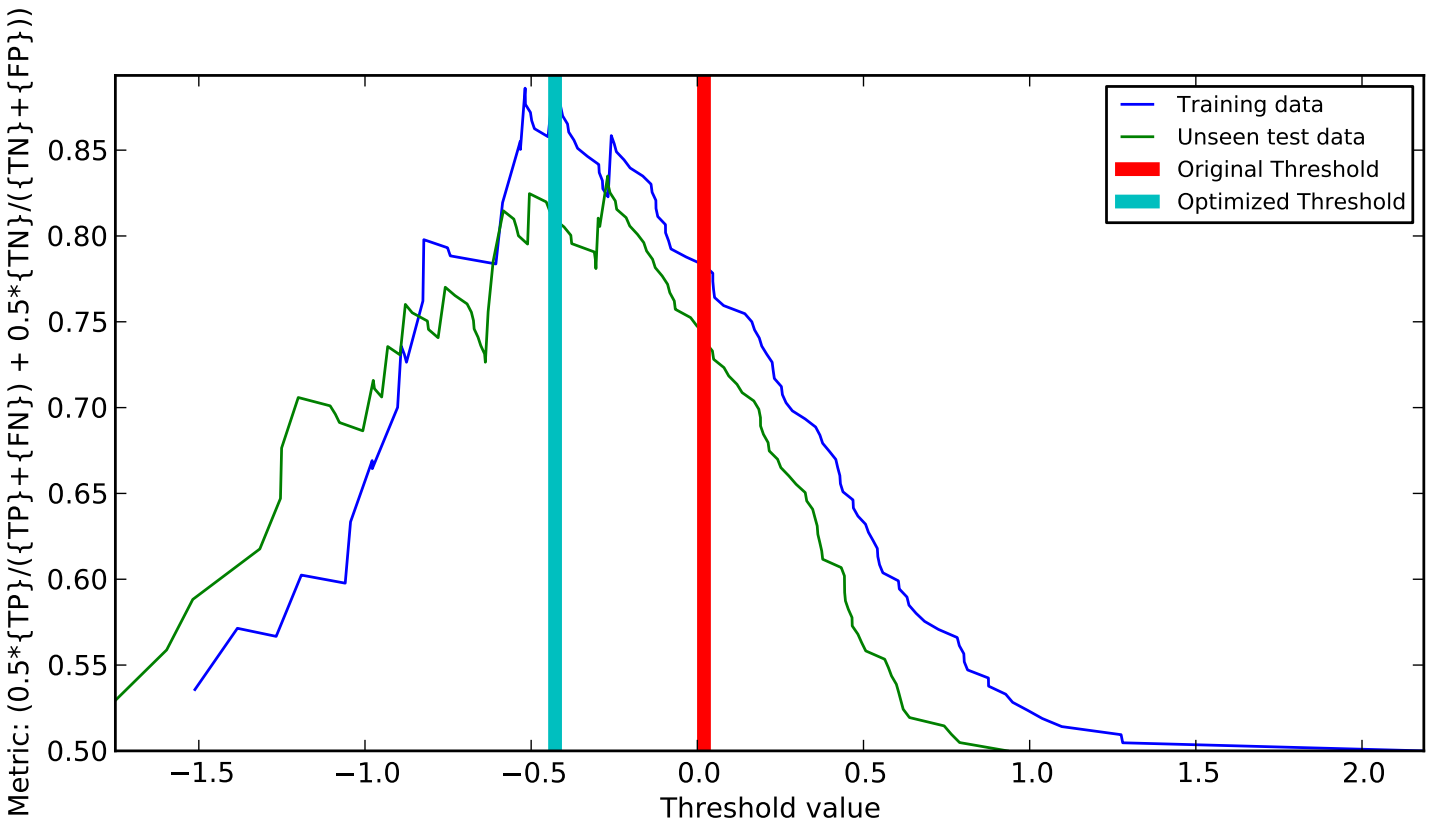
- Adaptation to Missed Targets by optimizing t such that performance on training data for "Missed vs. Recognized Target" is optimized
- Lower-dimensional learning problem - only one parameter needs to be optimized!
- Because of the similar patterns of Standards and Missed Targets, there are good chances that $\mathbf{w}$ learned for "Standard vs. Rec. Target" works also for "Missed vs. Rec. Target"

Performance Metric: Balanced Accuracy

- Because of the strong class skews, standard metrics like accuracy are not suited for performance evaluation
- Because of varying ratios of Missed to Recognized Targets, performance metric should be independent of class distributions in test data
- Balanced accuracy is such a metric:

$$acc_{bal} = 0.5\frac{TP}{TP+FN} + 0.5\frac{TN}{TN+FP} = 0.5*(sensitivity + specifity)$$

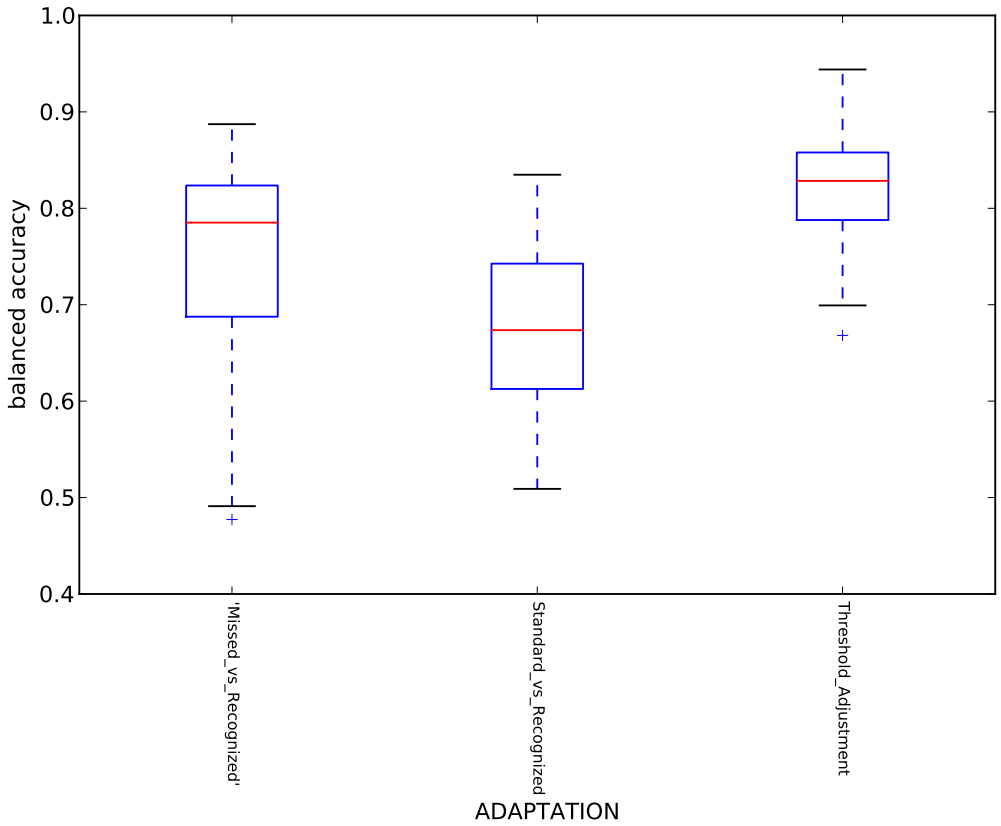
Threshold Adjustment



Experimental Setup

- Dataset recorded in BRIO Oddball paradigm consisting of 12 sessions of 6 subjects (2 sessions each)
- Each session consists of 5 runs (repetitions) of the paradigm, each run lasting for approx. 16 minutes
- First run of a session used to train data flow to distinguish Standard and Recognized Targets
- Second run of a session used to adapt data flow such that it can distinguish Missed and Recognized Targets
- Remaining 3 runs used for evaluation

Performance Evaluation



Outlook

- Other classification algorithms that allow a fast adaptation of the whole classifier
- Online adaptation concurrently to session to deal with non-stationarities within a session

Thank you for your attention

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Questions/Comments are welcome!

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