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Impact of target-to-target interval on classification performance in the P300 speller

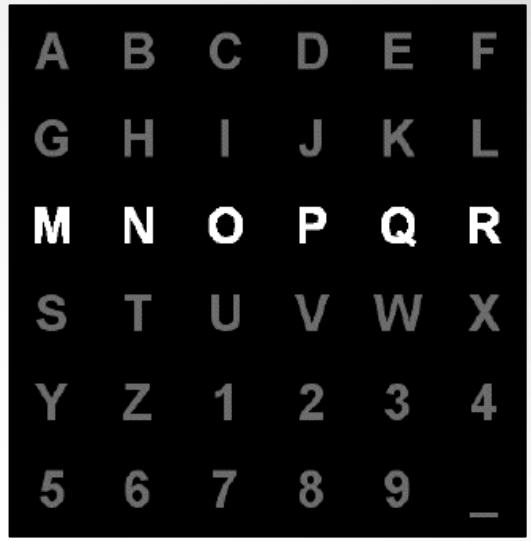
Suzanne Martens[1]
Jeremy Hill[1]
Jason Farquhar[1]
Bernhard Schölkopf[1]

[1] Empirical Inference Department
Max Planck Institute for Biological Cybernetics
Tübingen, Germany

suzanne.martens@tuebingen.mpg.de

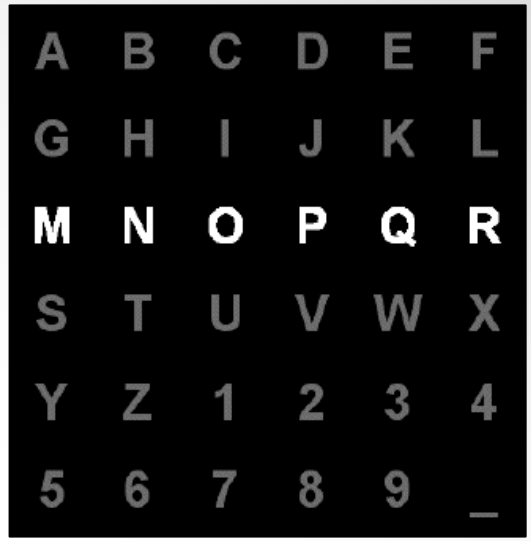
P300 speller in general

- Brain-Computer Interface for spelling words
- Possible means of communication for paralyzed patients with intact visual system [Nijboer_unpubl]
- Uses discriminative properties of event-related potentials (ERPs) in response to target/attended (T) and non-target/non-attended (N) stimuli.
- Setup has hardly changed since it's introduction in 1988 [Farwell_1988]



Mechanism of character prediction

- Stimuli are flashing characters organized in a matrix on a screen, flashing in a random/unpredictable order.
- Target character is the character that the subject wants to communicate
- EEG corresponding to each flash (epoch) is stored (~1 s)
- Classifier is trained (on known characters) such that it can discriminate between target (T) and non-target (N) epochs
- After all rows and columns have flashed and all epochs have been classified, the target character can be predicted



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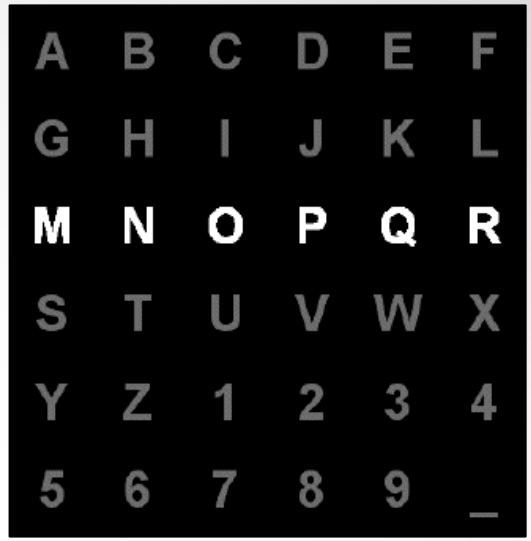
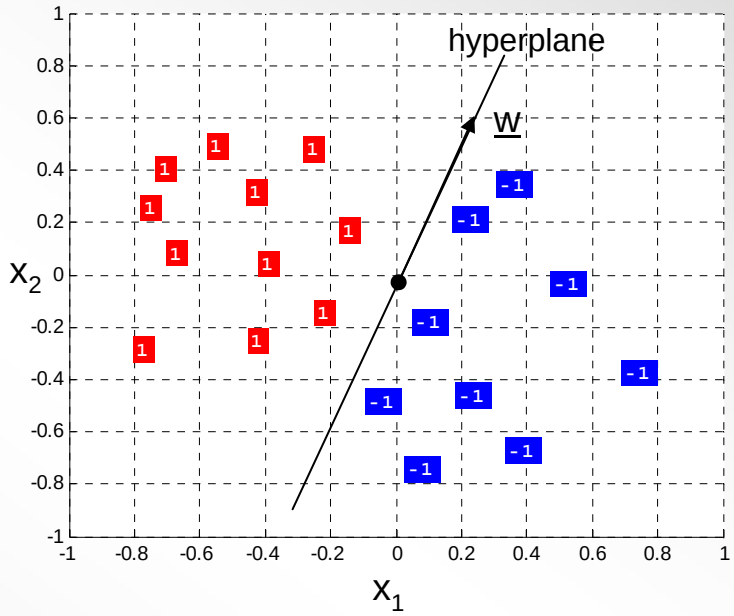


Epoch classification, $y = \underline{x} \cdot \underline{w} + b$

- $\underline{x}$ are the samples in one epoch (target or non-target, in figure: red vs blue)
- the classifier finds a hyperplane with direction $\underline{w}$ and intercept ("bias") b that "optimally" separates the two classes (targets and non-targets)
- criteria for finding $\underline{w}$ and b:
  - SVM: maximize the distance of the nearest training points to the hyperplane
  - LDA (Fisher): maximize between-class variance relative to the within-class variance
- y>0: assign $\underline{x}$ to class 1,
  y<0: assign $\underline{x}$ to class 2



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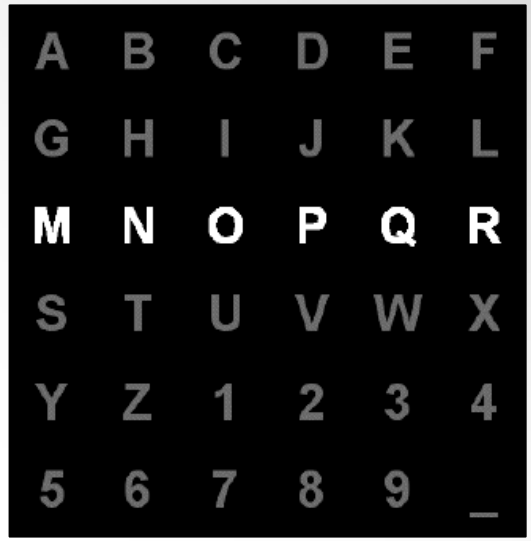
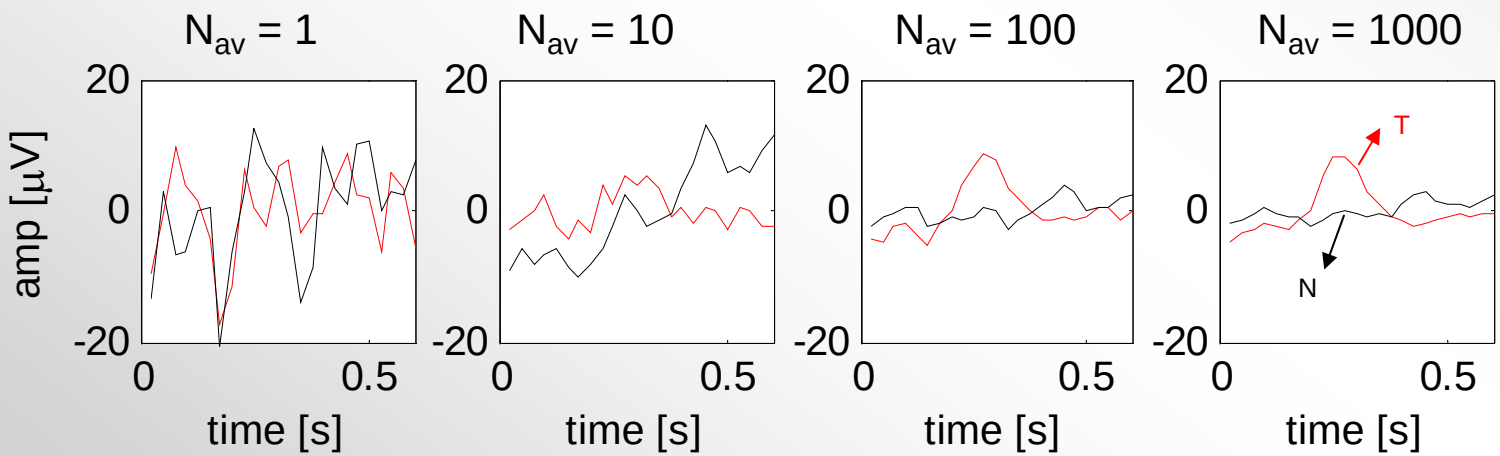


Challenge

- Increasing the bitrate (nr of correctly predicted characters per time interval) without a reduction in accuracy.
  - Poor SNR hampers classification
  - Signal denoising techniques to improve SNR are limited
  - Repetitions of flashing rounds are needed to reliably predict the character

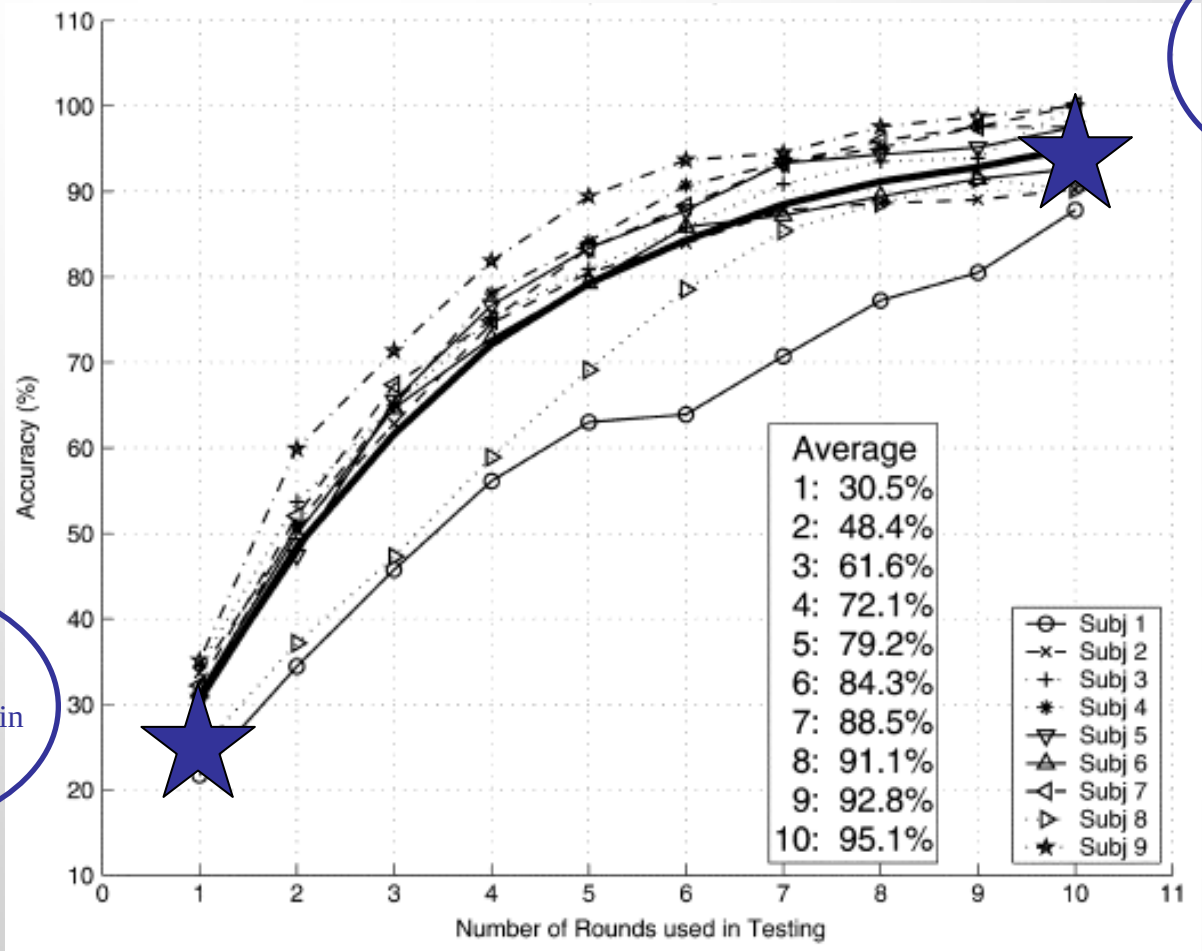


State of the Art [Thulasidas_2006]

speed = 2 char/min

bitrate = 2.1 char/min

accuracy = 100%



speed = 13 char/min

bitrate = 2.6 char/min

accuracy = 20%

ISI = 175 ms

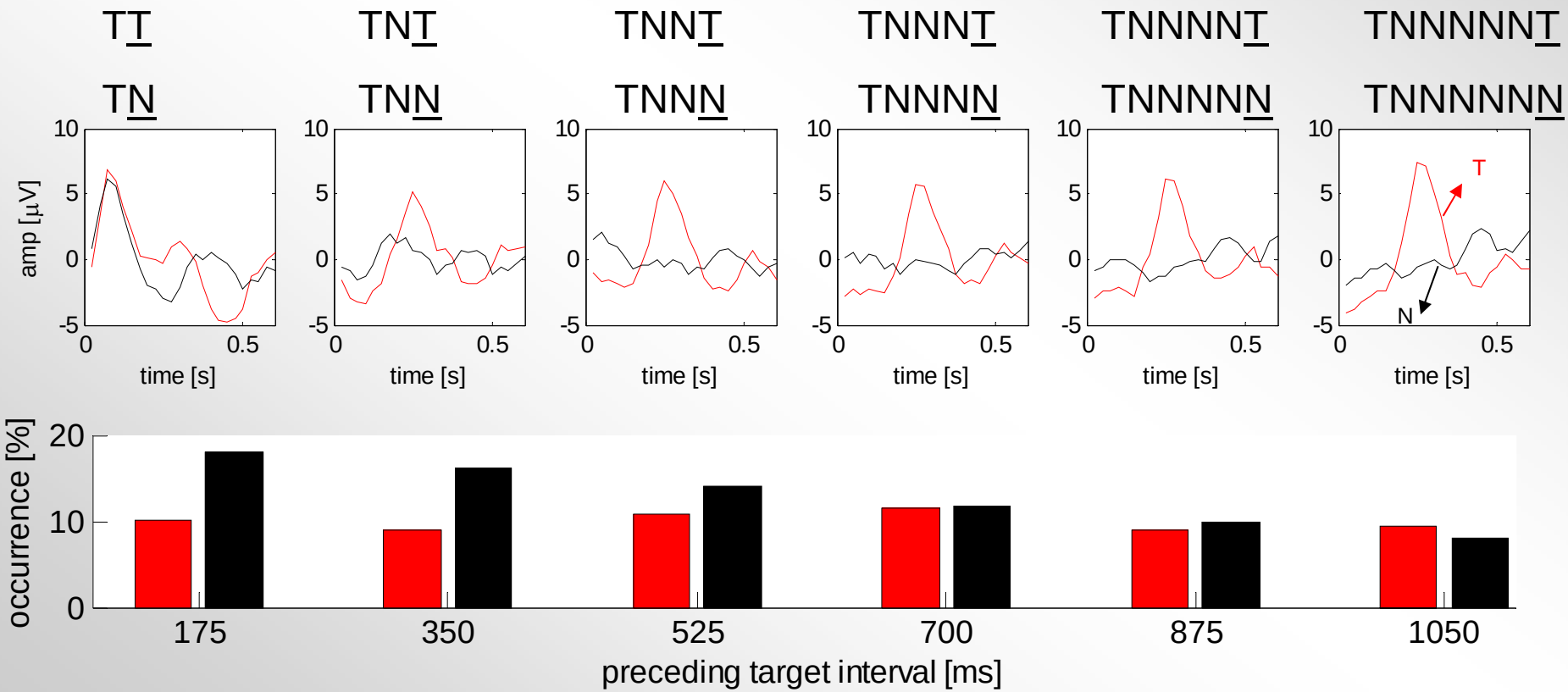
Increasing the accuracy/bitrate of character prediction

- Use of repetitions
- Use of small interstimulus intervals (ISI) ~100 ms

However

- Duration of the ERP (~1 s) is LARGER than the ISI (~100 ms)
  - ERP overlap effects [Woldorff_1993] ??
- Due to the randomized flash order, the interval between two targets (TTI) may be as large as a few seconds BUT AS SMALL AS ~100 ms
  - ERP refractory effects [Woods_1980] ??

ERP overlap and refractory issues in the P300 speller



Research question

- Does the performance of the P300 speller suffer from ERP overlap and refractory effects?

Approach

- Forget for a moment character prediction and focus on epoch classification
- Analyze the epoch classification performance for targets and non-targets as a function of the preceding target interval (pTI)
  - Target epoch loss = # incorrectly classified T epochs/# T epochs
  - Non-target epoch loss = # incorrectly classified N epochs/# N epochs
  - Epoch loss of 0.5 is chance performance
- P300 speller data from 4 subjects

  I ALS patient[1], 16-channel EEG

  II ALS patient[1], 16-channel EEG

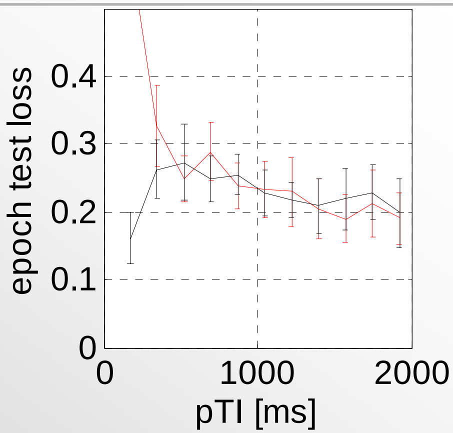
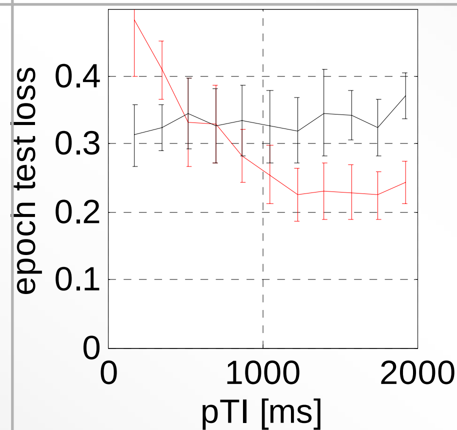
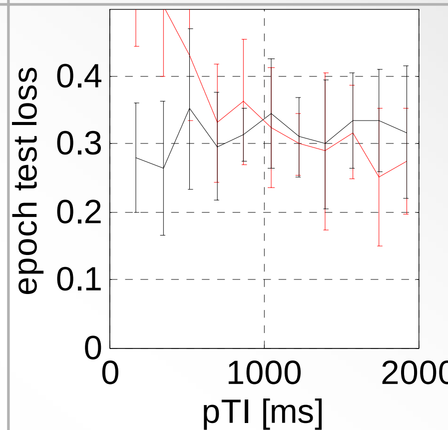
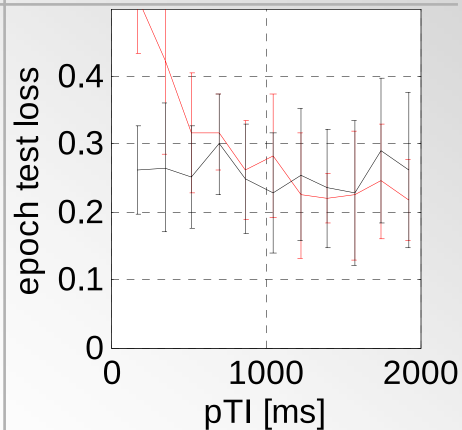
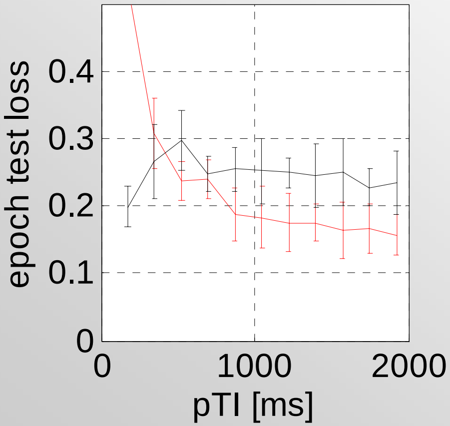
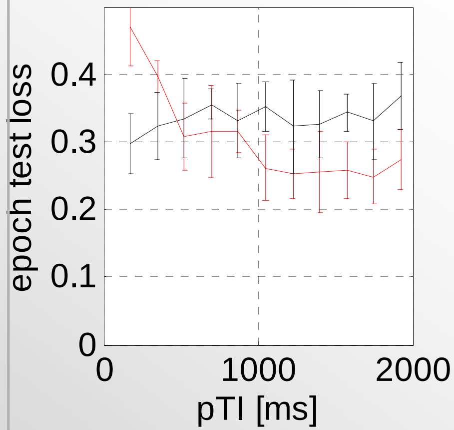
  III Healthy subject, BCI competition 2003 IIA[2], 64-channel EEG

  IV Healthy subject, BCI competition 2003 IIB[2], 64-channel EEG

[1]Provided by Institute for Medical Psychology and Behavioral Neurobiology, University of Tübingen, Germany

[2]Provided by Wadsworth Center, NYS Department of Health, Albany, USA

Classifier performance as a function of preceding target interval (pTI)

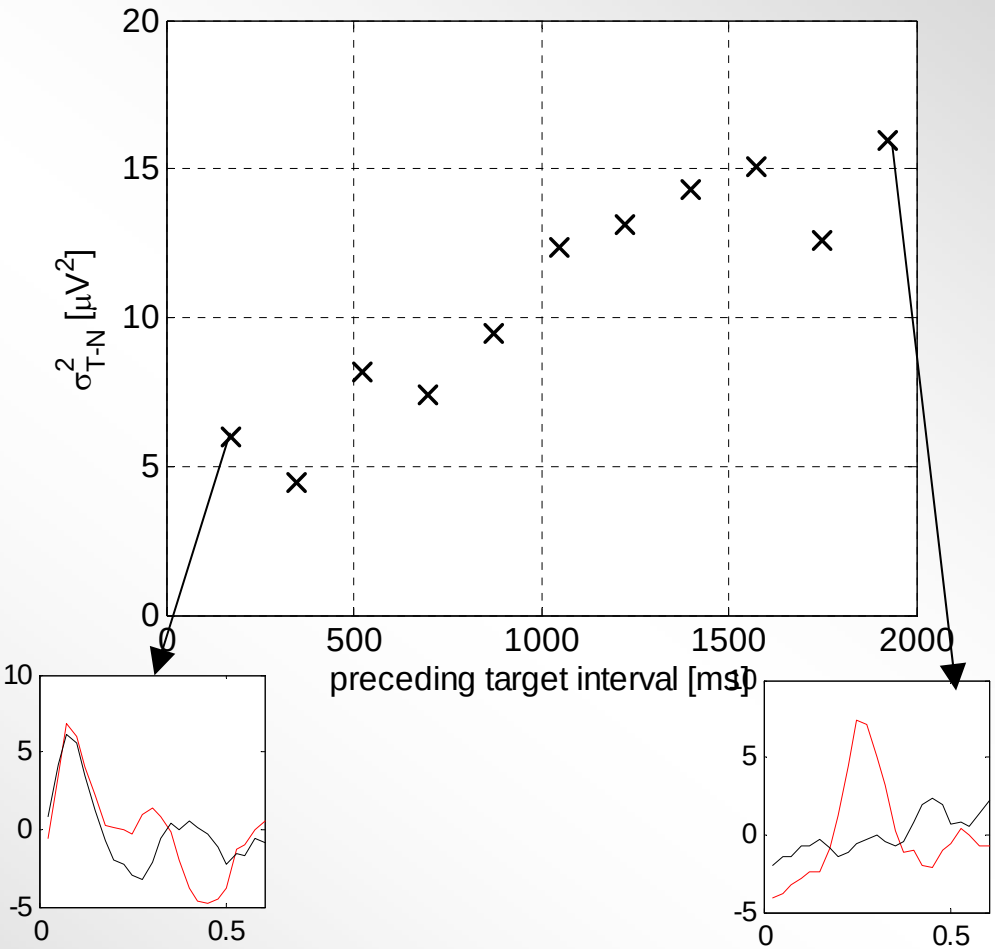
	dataset I	dataset II	dataset III	dataset IV
SVM				
LDA			rejected	rejected

Conclusions

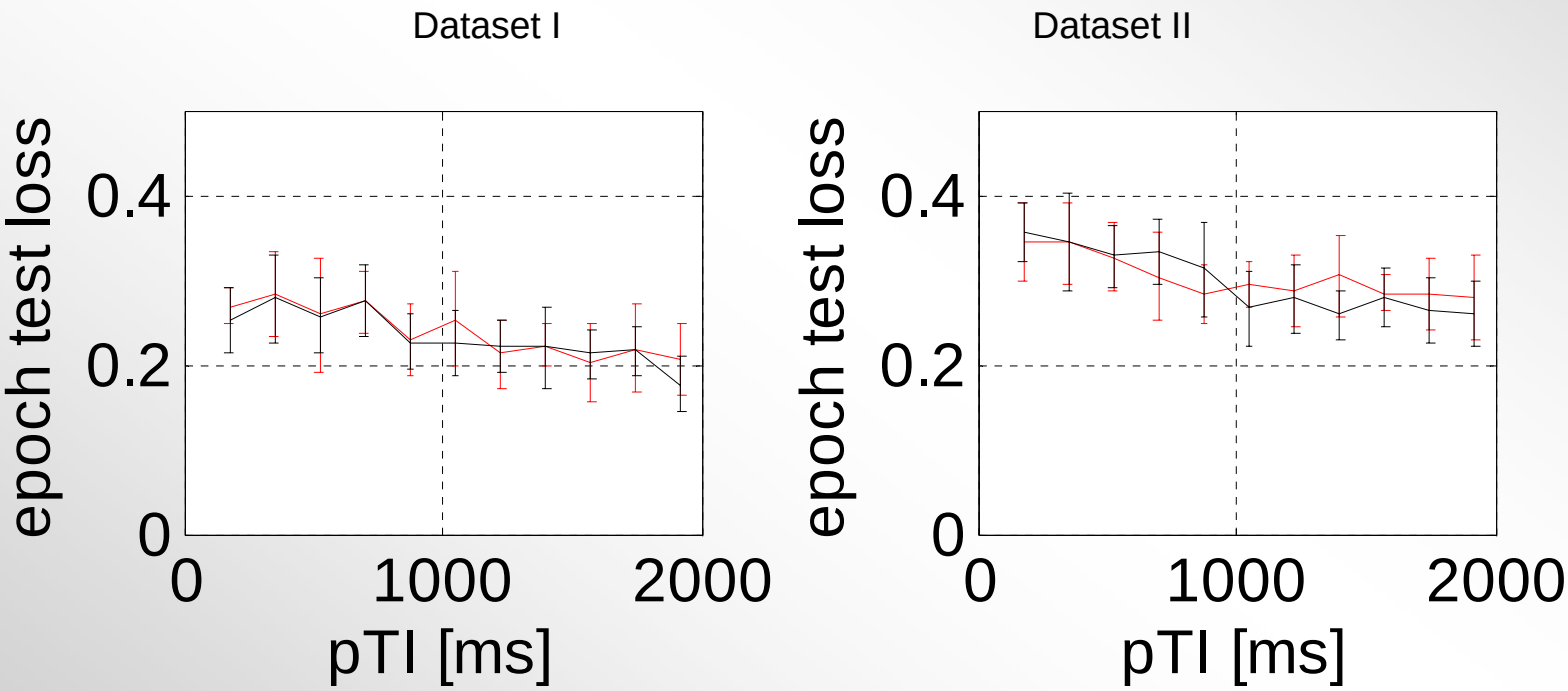
- ERP overlap and refractory effects are significant for targets with a pTI<1000 ms
- The targets with a pTI < 500 ms display a classification accuracy that approximates chance performance
- These targets (~20% of all targets, when ISI=175 ms) do therefore not transfer any classification information
- There is room for improvement of the P300 speller performance

Ideas

- Ensure that targets always have pTI>1000 ms
  - e.g., single character flash code instead of row-column flash code
  - bitrate ↓ ??
- Design the flash order such that frequently-used characters have large pTI
  - accuracy of rare characters ↓
- Try to classify all targets as good as possible
  - train a different classifier on each pTI
  - possible for small pTI???
  - pTI is only known for the training set

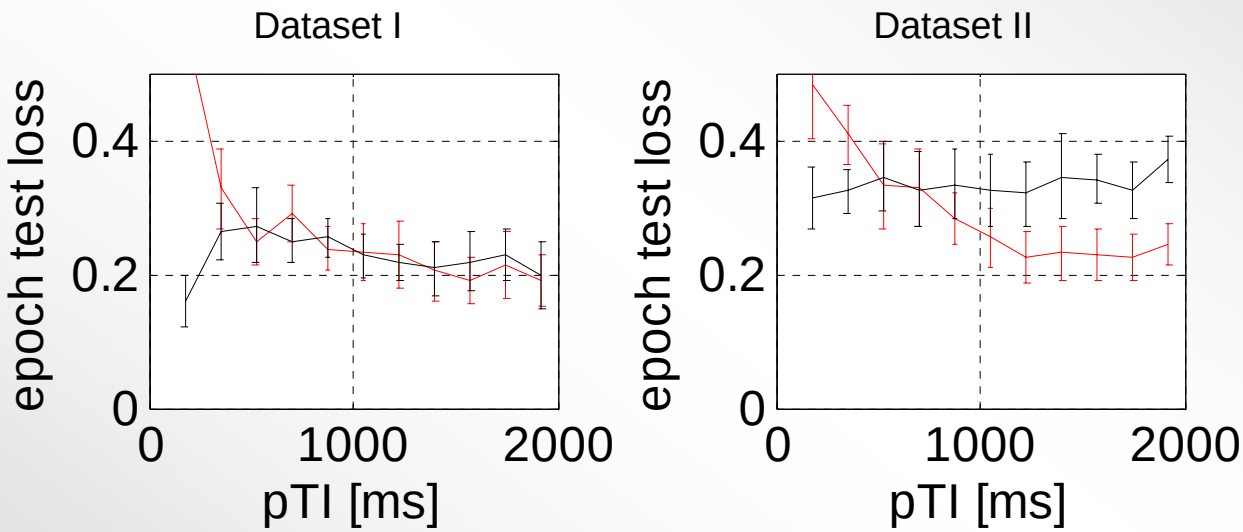


Classification results when using different classifiers (SVM) for different pTI



To conclude

Training one classifier on all pTI…

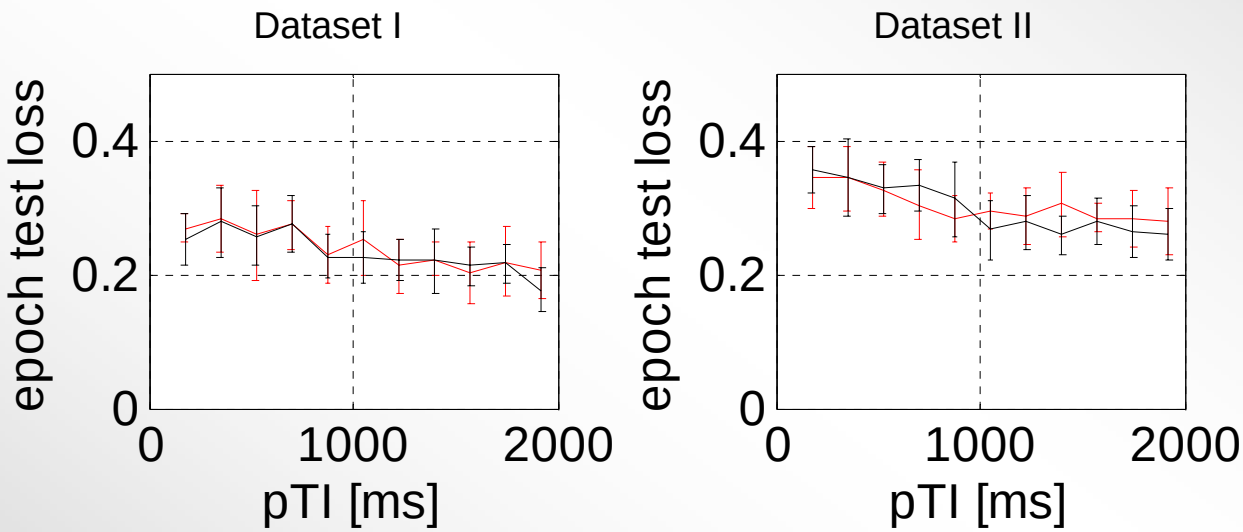


… and loosing classification information

in about 20% of the targets

Or

Training different classifiers for different pTI…



… and using the formerly classified epochs to predict the pTI,

i.e., to predict which classifier we should apply for the current epoch?

References

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