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Investigating the Effect of Inter-Letter Spacing Modulation on Data-Driven Detection of Developmental Dyslexia Based on Eye-Movement Correlates of Reading: A Machine Learning Approach

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Outline

- Background, motivation

- Materials (participants, paradigm, stimulus)

- Methods (feature selection, classification)

- Results

  - Classification performance

  - Important features

- Conclusions

Importance

- Developmental dyslexia [1]

- Eye-movements of dyslexic readers [2]

    - Shorter and more saccades

    - Longer and more fixations

- Effects of intra-letter spacing

    - Crowding [3, 4, 5]

    - Larger intra-letter spacing [6, 7, 8]

Materials and Methods

- Participants:

  - 24 dyslexic and 24 control young adults

- Experimental setup

- Natural reading

  - 250 sentences

  - 5 spacing levels (Sp1 to Sp5;

    0.7, 1, 1.3, 1.6, 1.9 times normal spacing)
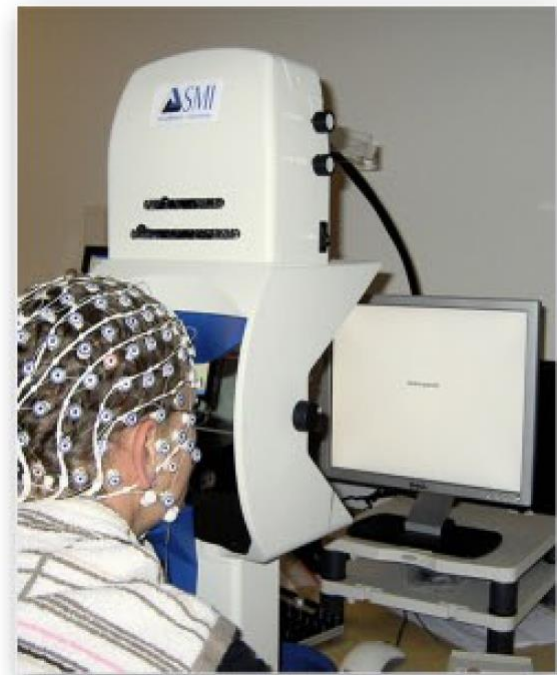
Materials and Methods

Methods

- Adaptive algorithm [9]

  - Fixation, saccade and glissade -> 65 measures

- Classification (Linear Support Vector Machine)

- Feature selection

  - Forward SFS (FSFS), Backward SFS (BSFS), RFE, LASSO, Elastic Net (ENet)

- Hyperparameter optimization

- Nested 10 times repeated 10-fold stratified cross-validation

- Standard cross-validation for overfitting estimation
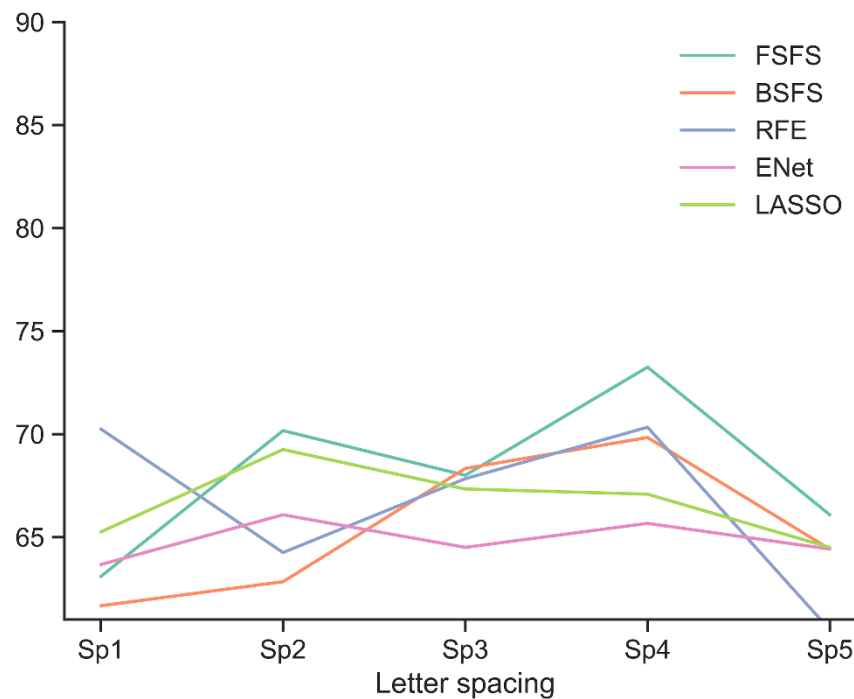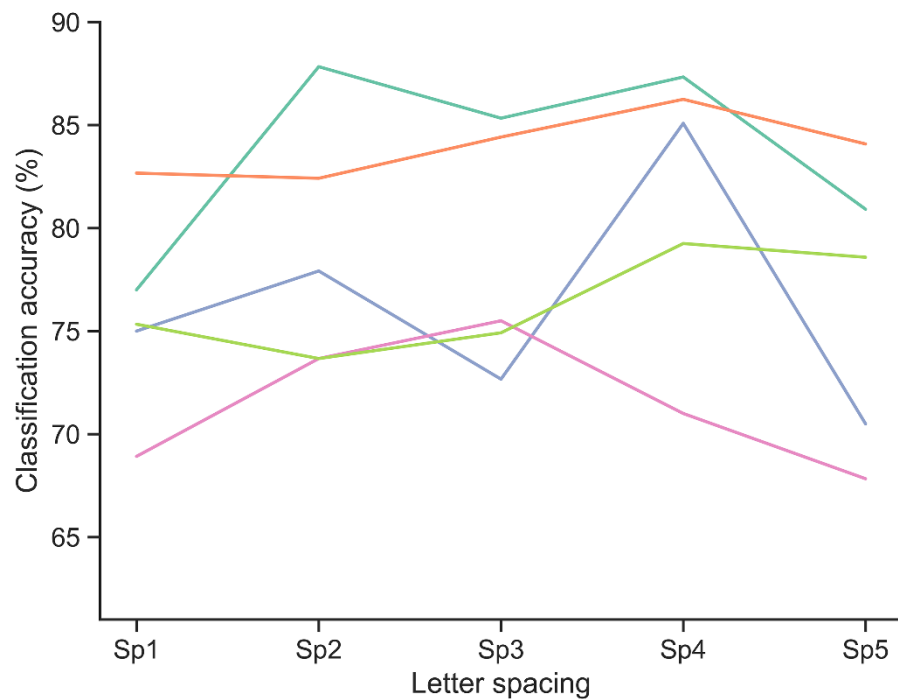
Methods

- Feature importance metrics

    - Selection frequency

    - Individual accuracy

    - Added accuracy

    - Leave-out accuracy decrease

- Classification accuracy metrics

    - Best subset accuracy

    - Ranked max accuracy

    - Per iteration max accuracy

- Kappa analysis for statistical comparison of classification accuracies

Results
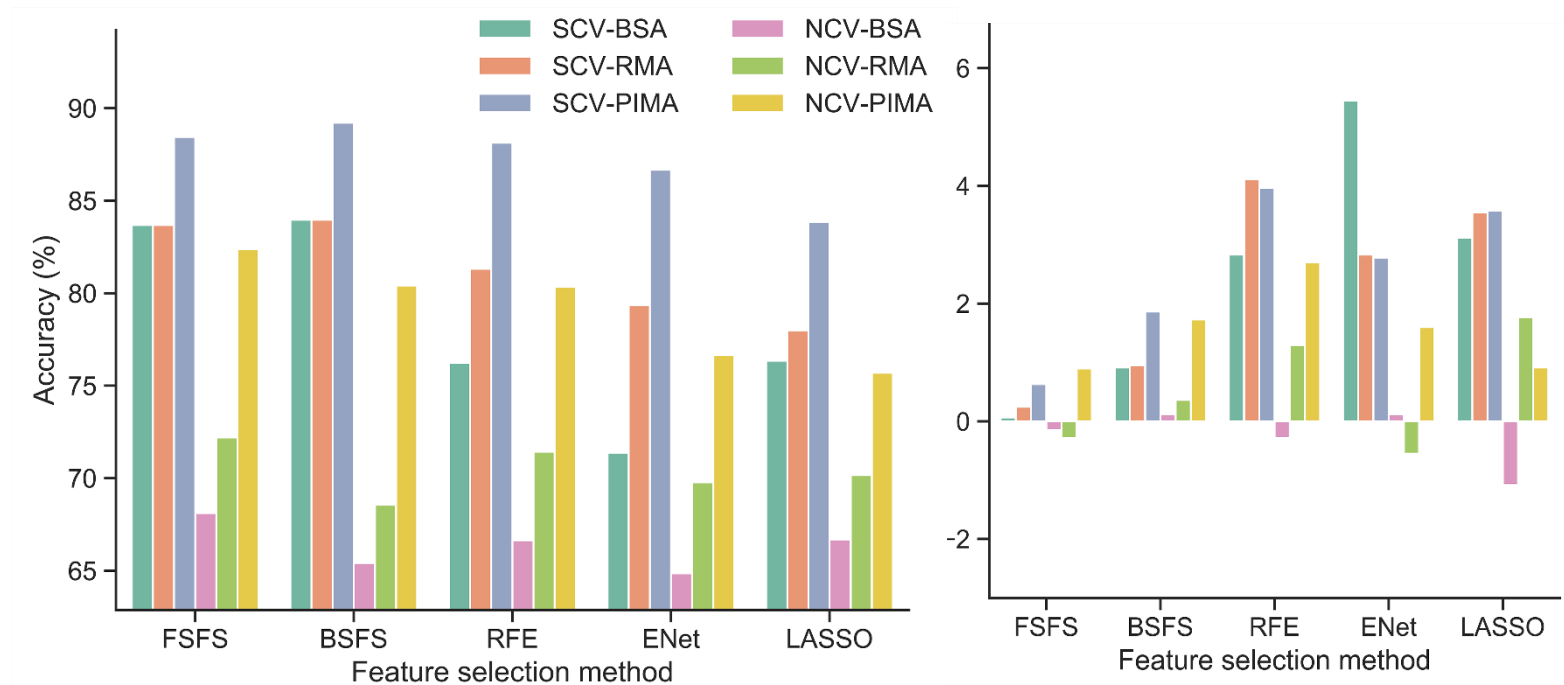
Best subset (BSA), ranked max (RMA) and per iteration max accuracy (PIMA) metrics averaged across the letter spacing conditions for all feature selection methods, using standard (SCV) and nested (NCV) cross-validation without C optimization (left) and the change in classification acccuracy after C optimization (right).

Results

Best subset classification accuracy as a function of letter spacing (Sp) for all feature selection methods with standard (left) and nested (right) cross-validation without C optimization.
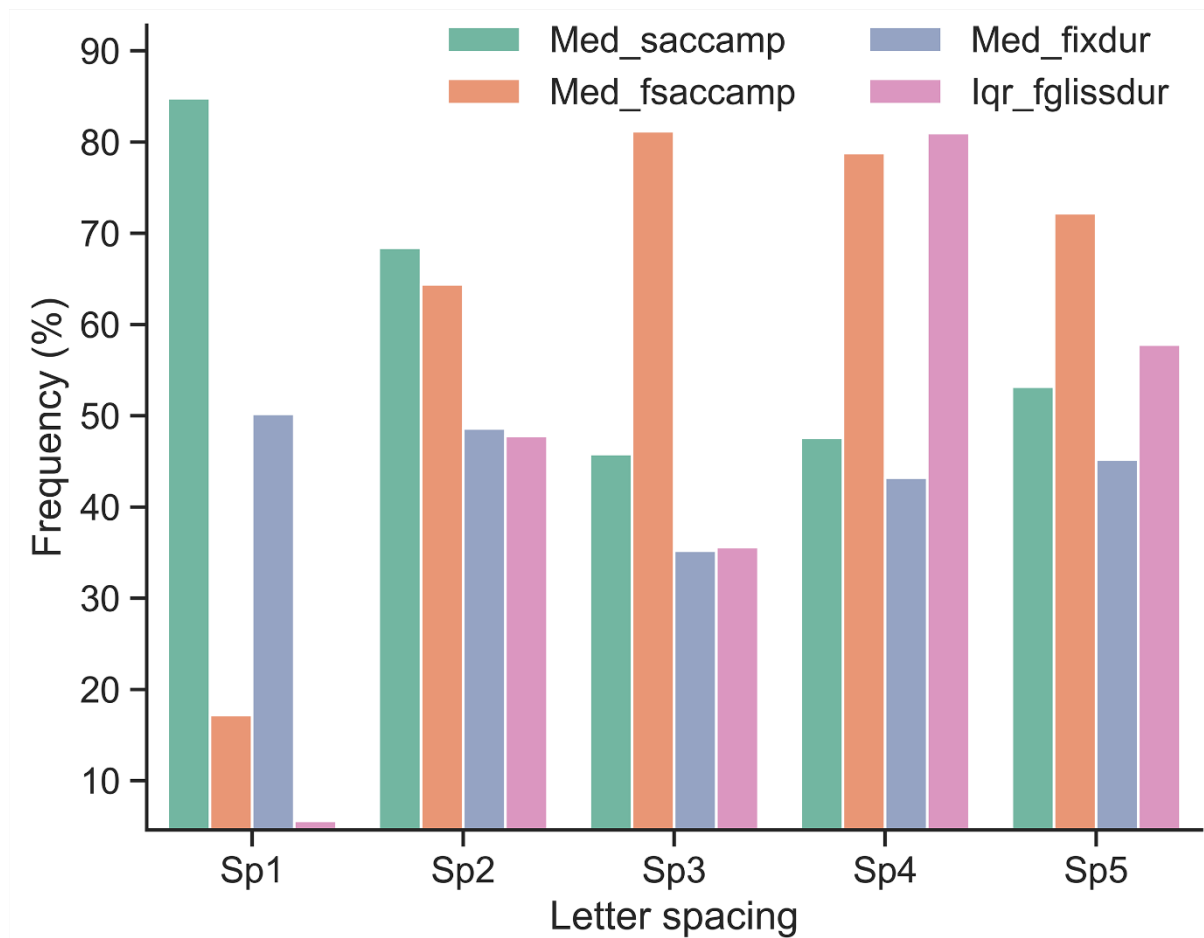
Results
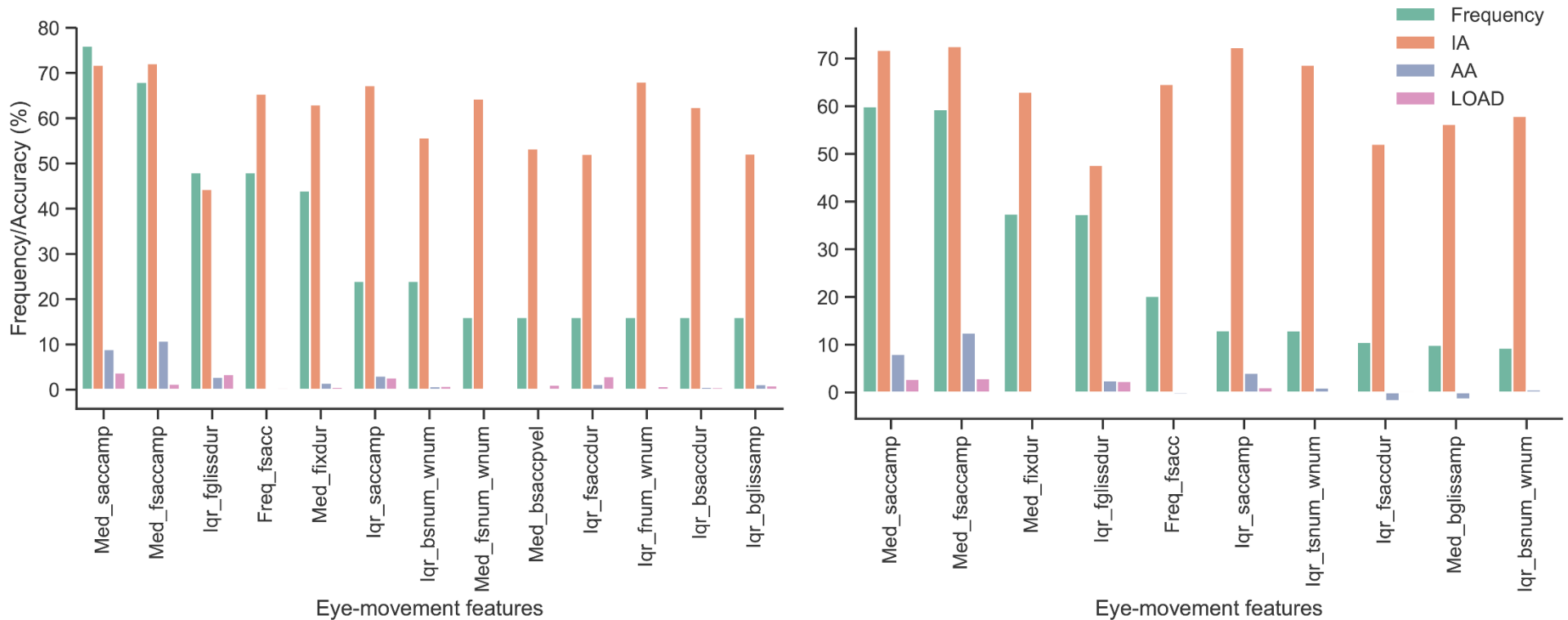
Performance of eye-movement features aggregated across feature selection methods and letter spacing levels for standard (left) and nested (right) cross-validation. IA=individual accuracy, AA=added accuracy, LOAD=leave-out accuracy decrease

Results

Selection frequency of the four most frequently selected features as a function of letter spacing (Sp).

Conclusions

- 73.25% maximal classification accuracy (Sp4)

- No significant effect of letter spacing

- Similar feature importance across letter spacing levels

- Importance of glissades

- Further work:

  - Reducing overfitting (6% increase in accuracy, work in progress)

  - Nonlinear classifiers (linear classifiers are sufficient, work in progress)

  - Combining features across spacing levels, regression analysis
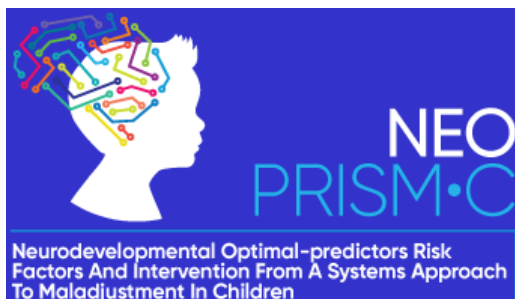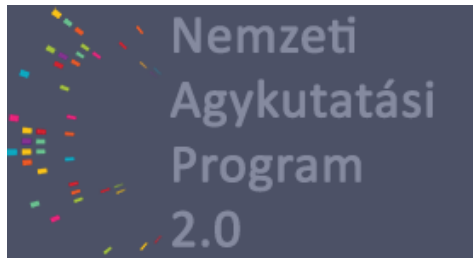
  - Translational capability

Acknowledgments

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Nemzeti Agykutatási Program 2.0

NEO PRISM·C

Neurodevelopmental Optimal-predictors Risk Factors And Intervention From A Systems Approach To Maladjustment In Children

Thank you!

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