Recognition of Reading Disorder Based on Eye-Tracking Data

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Motivation

Dyslexia is among the most common learning disabilities, affecting 5–10 % of the population [1], children and adults alike. The condition can impair the individual's academic and occupational performance, which may be minimised by early detection and support. Therefore, providing **fast and reliable diagnostic tools** at an early age is of great interest.

Eye-tracking technologies enable us to record eye movements during various activities [2], including reading. The differences in reading are well-studied and involve lower reading speeds or a higher chance of rereading already visited sections [3]. Such dissimilarities raise questions about the viability of machine learning in this area [4].

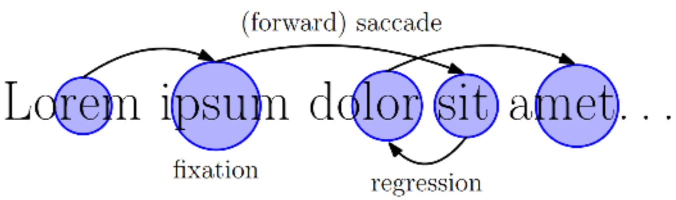


Figure 1. An example of the human gaze we attempt to detect: short and frequent stops (**fixations**) followed by quick movements (**saccades**)

Our goals

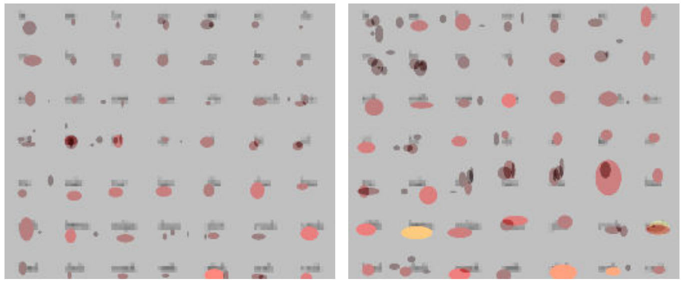
- Explore and summarise **the existing research** and identify both the state of the art and the gaps in used data representations and machine learning methods.
- Define the appropriate **representations** and **models** to cover the gaps found.
- Propose an experiment to deal with **limited** and **imbalanced data**.
- Verify the state-of-the-art approaches on tasks read by **Czech children**.
- Provide recommendations for **future research** and practical applications.

Data representations

A Faculty of Arts research team provided the data as part of a **pilot experiment** with the eye-tracking being enabled by SensoMotoric Instruments solutions.

The sample comprises **35 children** aged 9–10 (**22 intact** and **13 dyslexic**) and 4 reading tasks (called Grid, Hard text, Easy text and Pseudo-text).

The statistics-based representations (gaze event statistics: on the entire task; per Area of Interest; per time window) are the state-of-the-art approaches, which were compared to the proposed ones: **fixation sequences** and **visualisations**.



(a) Intact (b) Dyslexic

Figure 2. Illustrations of the *grid* reading task overlaid by the rescaled fixture visualisations: the position of ellipses correspond to the position of the fixation, their size to the dispersion and the colour to the duration (brighter means longer)

Methodology

To handle the small dataset, 1 round of **stratified 5-fold Cross validation** was used for hyper-tuning and 10 rounds for testing. This can lead to some degree of data leakage (and over-fitting), but single splits would cause too much instability in results.

On the other hand, the class imbalance was solved by using **Balanced accuracy**, which can be compared to regular accuracy on balanced data.

Results

The explored models were **1-Nearest neighbour** for baseline (with DTW for sequences) and **neural networks** (MLP, GRU, CNN). The 4 resulting models for a given method were also combined into an **ensemble**.

Task	1-NN	Neural networks
grid	79.87 ± 16.17 %	**82.23 ± 13.58** %
easy text	83.55 ± 12.58 %	**85.22 ± 13.14** %
hard text	85.98 ± 13.01 %	**92.03 ± 9.48** %
pseudo-text	73.82 ± 16.67 %	**75.82 ± 15.41** %
ensemble	83.78 ± 14.54 %	**89.50 ± 12.30** %

Table 1. Ballanced accuracy of best models on each task

The results show that models trained on **the hard text** lead to the best outcomes, while ensembles generally lead to worse but more stable results. As for the models and data types, **the fixation sequences and visualisations** worked the best.

Conclusion

We have proposed a suitable combination of data representations and neural-network classifiers for dyslexia detection from eye-tracking data. The results are considered for publication in a journal paper. We have also identified further research areas, like investigating non-reading tasks or considering alternative machine-learning classifiers.

References

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