Eye movements during reading in Russian-speaking children with dyslexia

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Dyslexia

Dyslexia is a neurodevelopmental reading disability that impedes reading fluency and text comprehension despite normal intellectual capacity (Benfatto et al., 2016).

Dyslexia affects around 10% of the population (Sprenger-Charolles et al., 2011).

Most prominent theories:

- magnocellular theory (Stein, 2001) → poor oculomotor performance → poor reading performance
- phonological theory → disrupted phonological processing / impaired processing of speech rhythms → poor reading performance

Reading and phonological processing

Better phonological processing is associated with faster reading speed (e.g. Wagner & Torgesen, 1987; Bus & Van Ijzendoorn, 1999) and vice versa (Wagner et al., 1994).

Inefficient phonological processing contributes to poor silent reading fluency (Ashby et al., 2019).

More complex phonological processing has higher predictive value for reading fluency during reading out loud (Dorofeeva et al., 2020).

Previous eye-tracking studies

The eye movement patterns in children with dyslexia compared to controls (overview in Kirkby et al., 2008):

- longer fixation durations (especially for longer words)
- larger numbers of fixations (especially for longer words)
- shorter saccade lengths
- more regressive movements
- less skipping of short words

→ eye movement difference is associated with linguistic processing (e.g. Hutzler et al., 2006)

Research questions

- How do phonological skills influence eye movements during reading in children with phonological dyslexia compared to controls?

- Do linguistic properties besides length and frequency influence eye movements during reading sentences in children with dyslexia compared to controls?

Participants

Primary school students (1-4 grades):

- 29 children with diagnosed phonological dyslexia (mean age = 9.5; 19 boys)
- 47 children with normal reading (mean age = 8.5; 21 boy)

Reading fluency was assessed by the Standardized Assessment of Reading Skills in Russian (Kornev, 1997).

All children had normal hearing and normal nonverbal intelligence according to Raven’s Colored Progressive Matrices.

Materials 1: reading

Child version of the Russian Sentence Corpus (Laurinavichyute et al., 2019)

30 sentences 6-9 words long, e.g.:

- *С самой первой страницы история захватывает читателя*.
  From the very first page, the story captures the reader.
  История интересная? — Да / Нет
  Is the story interesting? — Yes / No

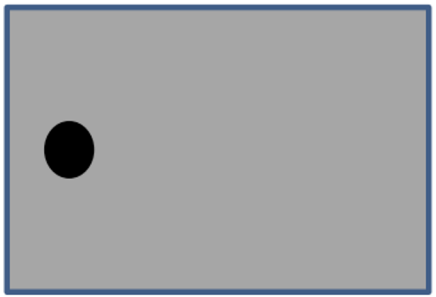
- *От смерти его спасла собака, которая приносила ему еду*.
  He was saved from death by a dog that brought him food.

Apparatus and Task

- Eyelink 1000+ Desktop mount eye-tracker with chin rest
- 9 points calibration, recalibration after 15 sentences
- Right eye was recorded
- Isolated sentences were placed in the middle of the screen
- Children were asked to read silently

Procedure

Fixation on black circle
500ms



Fixation on red circle
500ms

Materials 2: phonological processing skills

Russian Test of Phonological Processing (RuToPP) (Dorofeeva et al., 2019):

- phoneme discrimination (e.g. *vom-fom*)
- lexical decision;
- pseudoword repetition;
- phoneme detection (e.g. *g ... kit*; *ch ... vrach*);
- phoneme isolation (e.g. *Name the first sound in the word 'gitara'*)
- number of sounds;
- changing the sound in a pseudoword (e.g. *Replace the sound [l] with [v] ... mimila*).

Analyses

Dependent variables

- First fixation duration (FFD)
- Gaze duration (GD)
- Second run dwell time (SR)
- Total reading time (TT)
- Probability of skipping the word (S)

Analyses

Predictors

- group (dyslexia vs. control)
- grade
- mean accuracy in each of the RuToPP subtests
- word length
- word lemma frequency
- number of morphemes
- word class (noun, verb, adj, adv, pronoun, function words)
- morphosyntactic ambiguity
- base vs. nonbase word form

Dependent variables

- First fixation duration (FFD)
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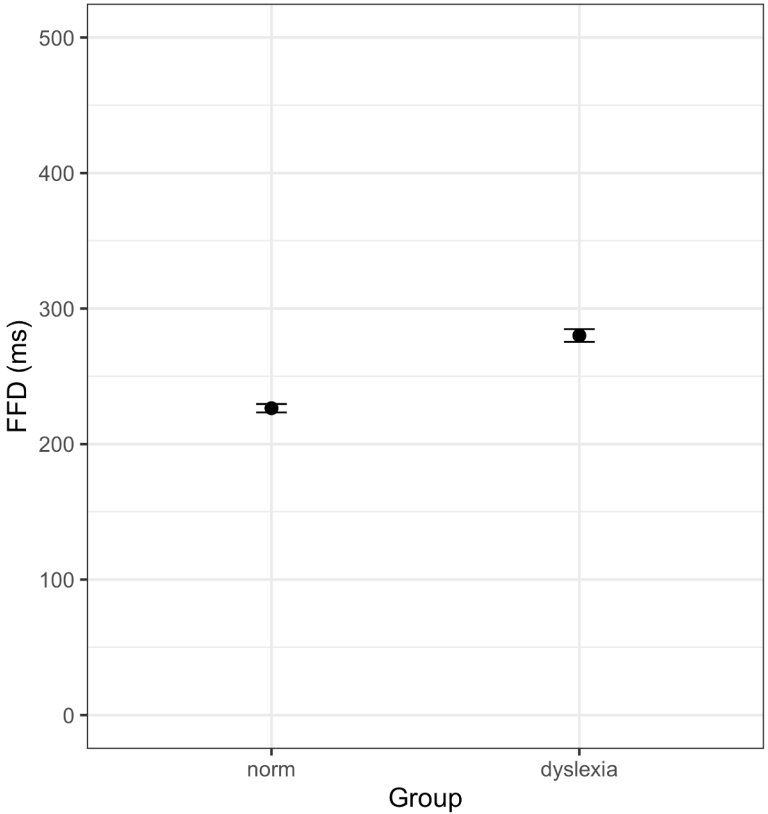
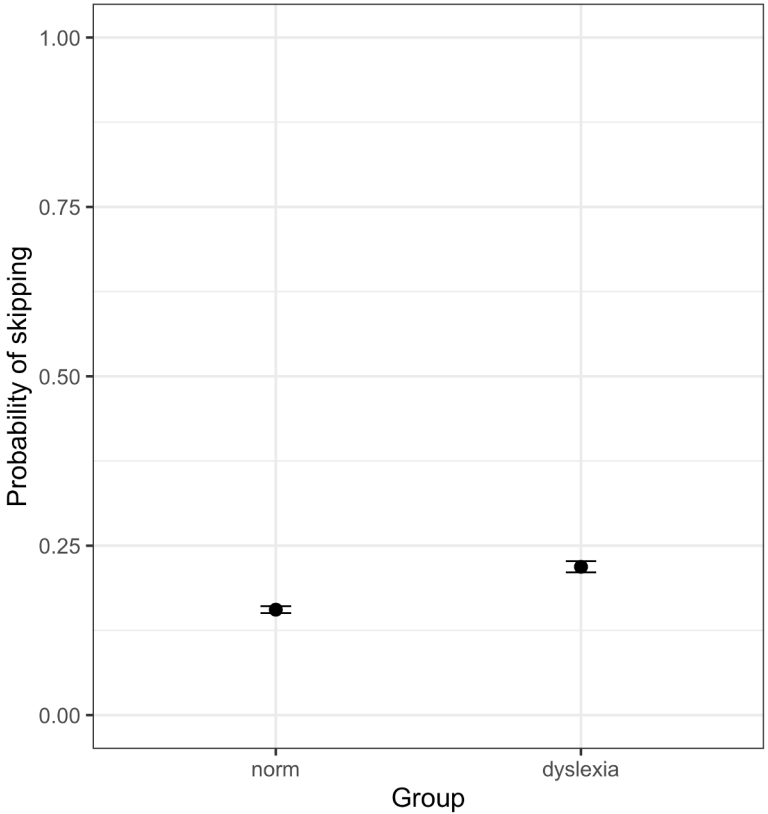
Children with dyslexia vs. controls



Overall children with dyslexia read slower than typically developing children (FFD, GD, SR, TT).

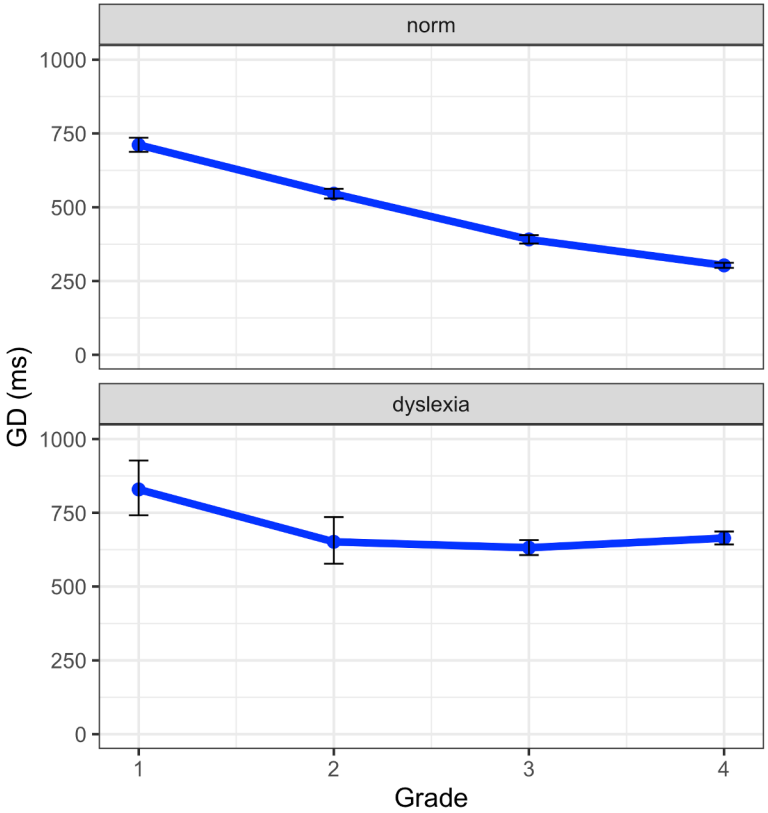
Children with dyslexia vs. controls



Overall children with dyslexia read slower than typically developing children (FFD, GD, SR, TT).

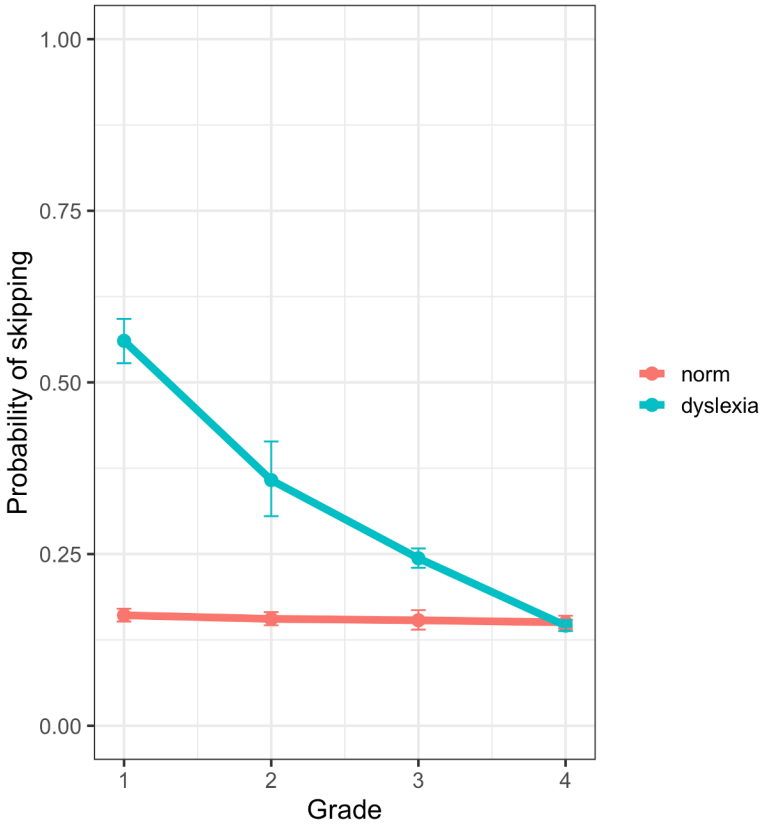
At the same time, children with dyslexia are more likely to skip a word (S).

Group * Grade interaction



Children from higher grade read faster (FFD, GD, SR, TT). However, this effect is less prominent in children with dyslexia (FFD, GD, SR).

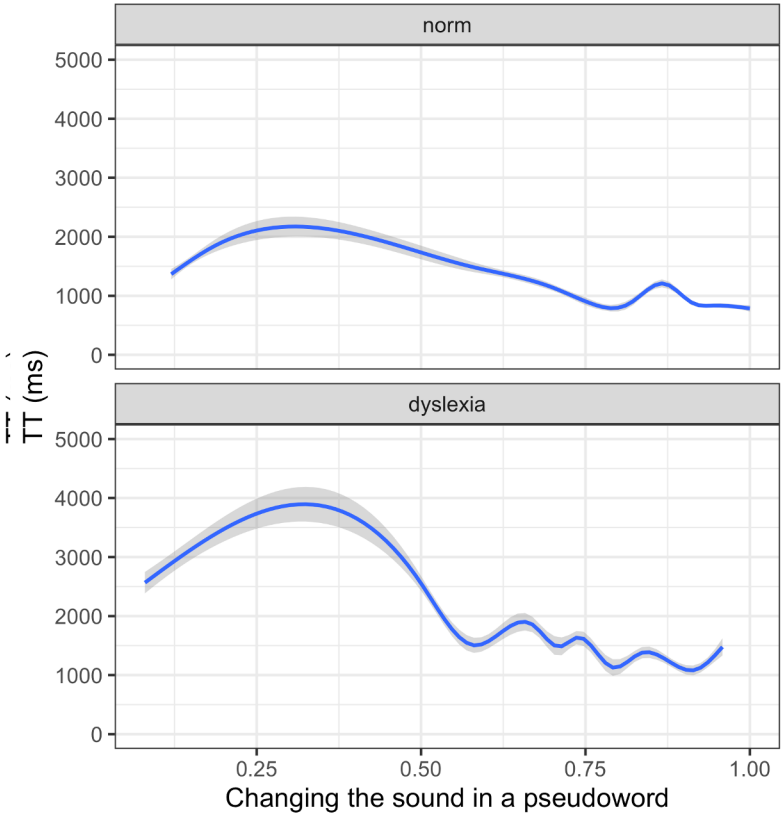
Group * Grade interaction



Children from higher grade read faster (FFD, GD, SR, TT). However, this effect is less prominent in children with dyslexia (FFD, GD, SR).

Children from higher grade are less likely to skip a word (S). This effect is even more prominent in children with dyslexia.

Group * RuToPP subtests interaction



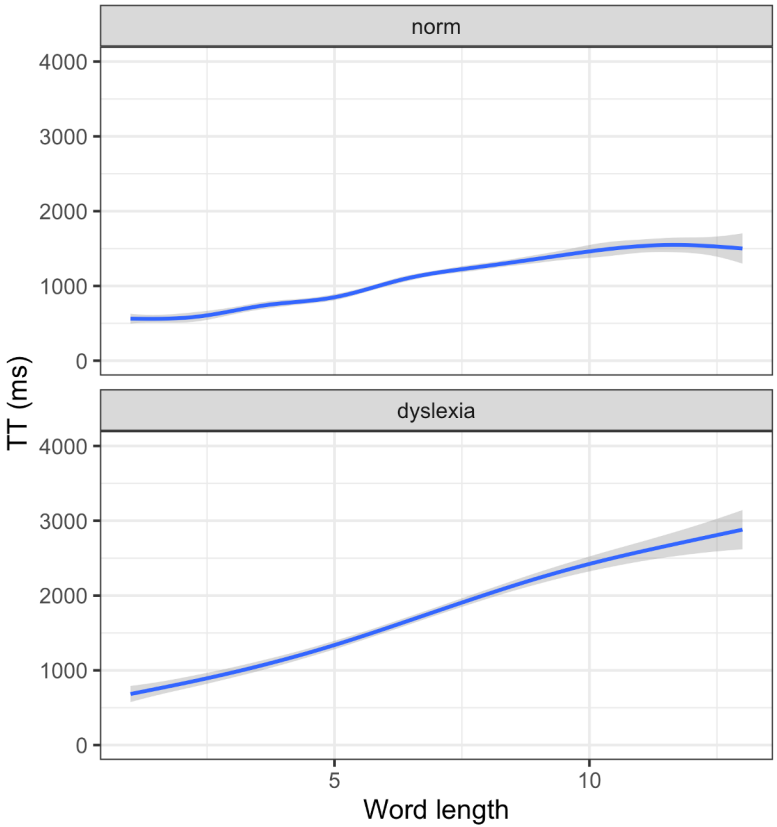
Better performance in two subtests (*Phoneme isolation; Changing the sound in a pseudoword*) is associated with faster reading times (GD, SR, TT).

The effect is more prominent in children with dyslexia, but only for the subtest *Changing the sound in a pseudoword* (SR, TT).

Group * Word properties interaction

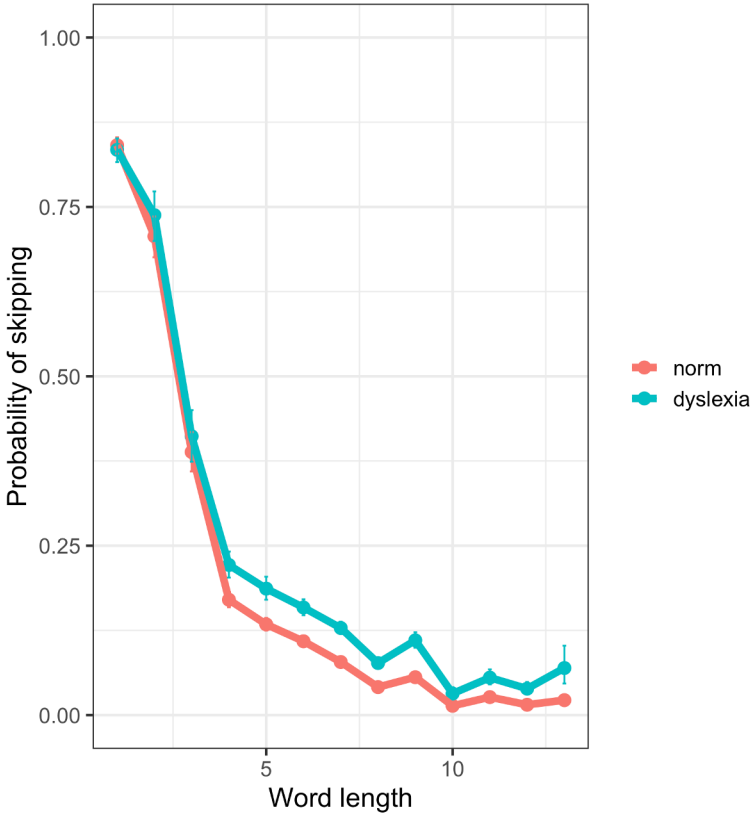
- **word length**
- word lemma frequency
- number of morphemes
- **word class** (noun, **verb**, adj, adv, **pronoun**, **function words**)
- base vs. nonbase word form
- morphosyntactic ambiguity

Word length



Longer words are read slower. This effect is even more prominent in children with dyslexia (TT).

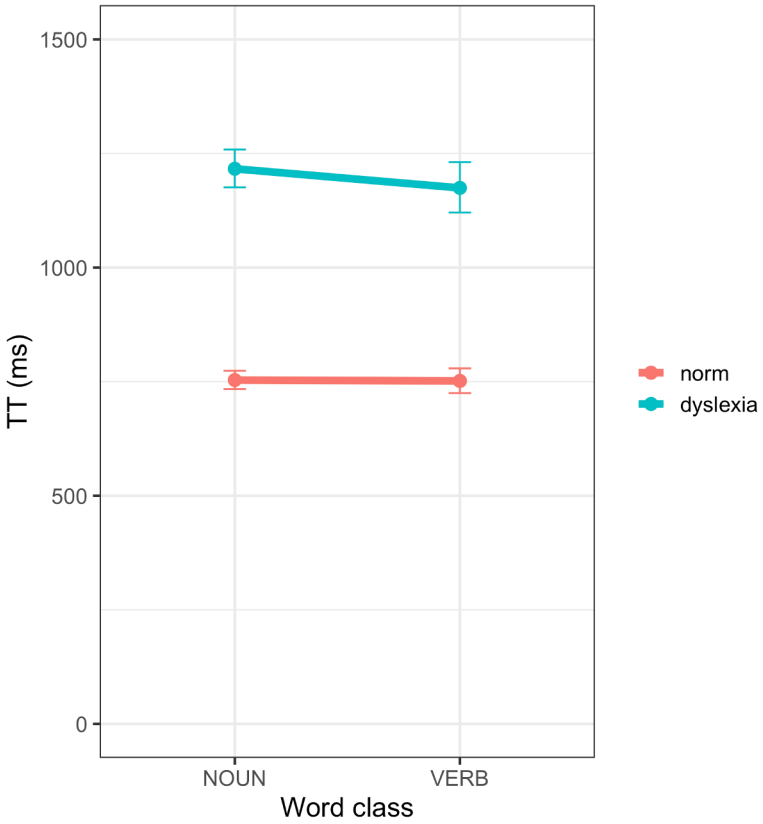
Word length



Longer words are read slower. This effect is even more prominent in children with dyslexia (TT).

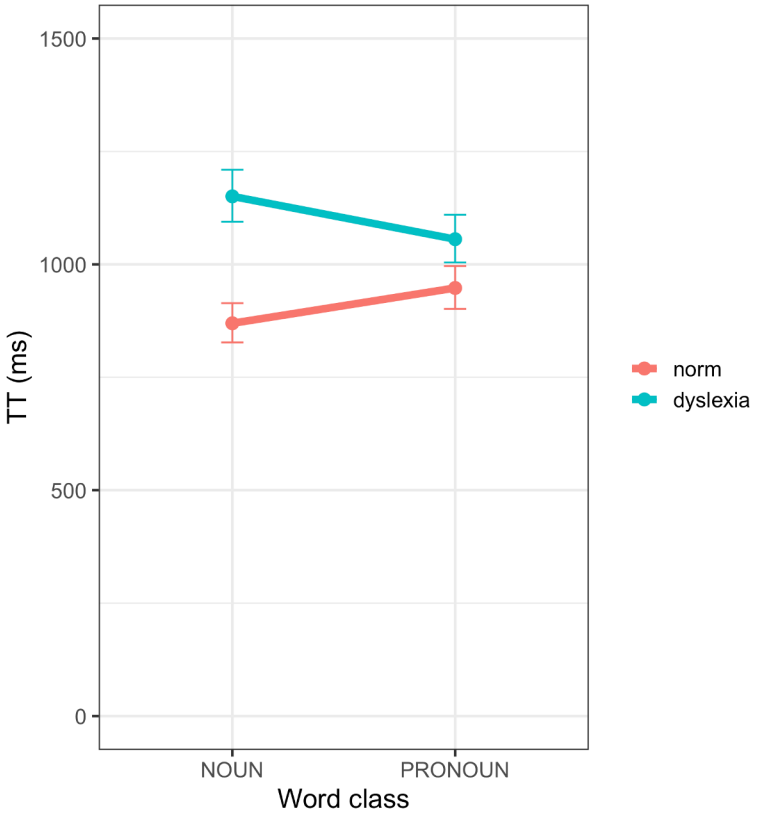
Longer words are more likely to be skipped by children with dyslexia compared to controls (S).

Word class



Verbs are read faster than nouns (GD, TT). The difference between the two word classes is even more prominent for children with dyslexia (TT).

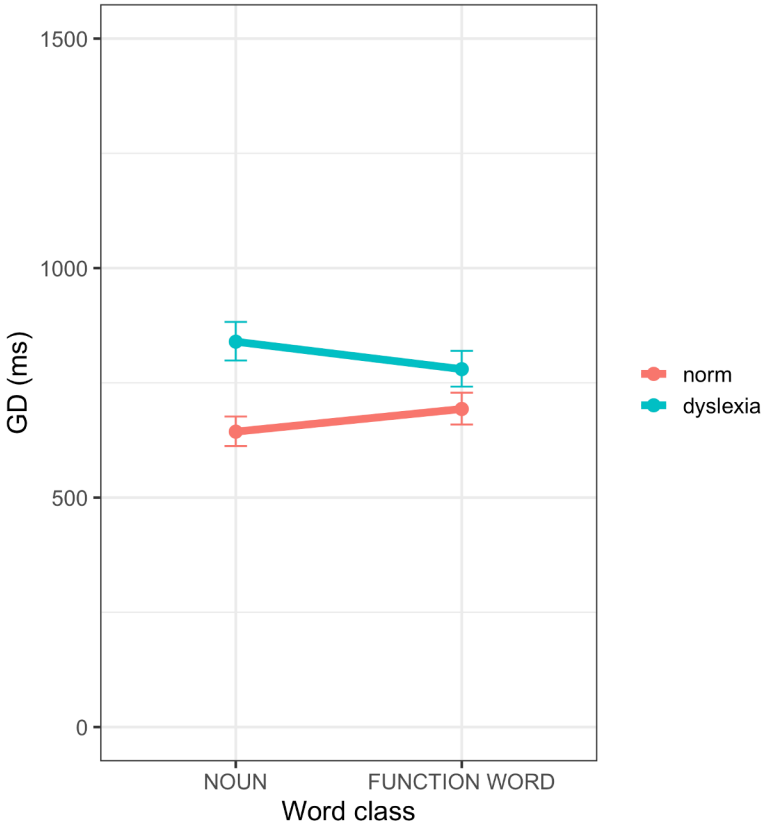
Word class



Verbs are read faster than nouns (GD, TT). The difference between the two word classes is even more prominent for children with dyslexia (TT).

Pronouns are read slower than nouns (FFD, GD, SR). However, the difference is less prominent for children with dyslexia (TT).

Word class



Verbs are read faster than nouns (GD, TT). The difference between the two word classes is even more prominent for children with dyslexia (TT).

Pronouns are read slower than nouns (FFD, GD, SR). However, the difference is less prominent for children with dyslexia (TT).

The same is true for function words (FFD, GD).

Results: all children

- Frequency: more frequent words are read faster (GD, SR, TT) and are more likely to be skipped.
- Morphosyntactic ambiguity: ambiguous word forms are read faster (FFD, GD, TT) and are less likely to be skipped.

No effect:

- Number of morphemes
- Base vs nonbase form

Discussion 1: phonological processing and reading

Difficulties with the most complex phonological task in RuToPP (*Changing the sound in a pseudoword*) are associated with longer fixations in children with dyslexia compared to controls.

→ Impaired complex but not elementary phonological processing prevents children with dyslexia from reading effectively.

Discussion 2: linguistic processing and reading

Interaction with Group:

- word length
- word class:
  - verbs are read faster than nouns;
  - children with dyslexia differ from controls in reading pronouns and function words

Only main effect:

No effect:

Discussion 2: linguistic processing and reading

Interaction with Group:

- word length
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- word lemma frequency
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Interaction with Group:

- word length
- word class:
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Only main effect:

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No effect:

- number of morphemes
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➞ The selected linguistic properties do not strongly distinguish between the two groups.

Discussion 3: reading strategies

➞ Skipping words and avoiding to read is a strategy that very young readers with dyslexia use.

➞ With more practice, older children with dyslexia are less likely to skip words and spend more time and effort on reading.