Towards automated literacy diagnostics: Insights from spelling error analysis

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Introduction

- Learning to spell is a complex task
  - Contribution and interaction of many different linguistic and cognitive components (Caravolas et al., 2012).
- Early detection of spelling problems is important
- Current standardized spelling tests yield limited diagnostic information
- Aim: Extract more detailed diagnostic information from children's spelling tests

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Research questions

1. To what extent can we automatically measure children's ability to apply spelling principles?
2. What are problematic spelling principles for below-average Dutch spellers?
3. Can we divide a group of Dutch below-average spellers into clusters based on their performance on applying specific spelling principles?

Method: Data set

- Participants: Dutch 3rd and 4th graders (8-10 years old) with below-average spelling skills
  - Grade 3: 85 participants
  - Grade 4: 63 participants
- Word dictations from *Lexima's Letterster*[1] software
  - Grade 3: 53 words
  - Grade 4: 66 words
- Same dictation was administered max. 3 times over the course of one school year

[1] https://lexima.nl/lezen/programmas/letterster

Method: Automatic detection of PCUs

- What is a **Phoneme-Corresponding Unit (PCU)** (Laarmann-Quante, 2016)
  → A sequence of graphemes that corresponds to one phoneme (e.g., school = s, ch, oo, l)

- Employ the algorithm described in Harmsen et al. (2021)

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Realized spelling (RS)
pandaa

Target spelling (TS)
panda

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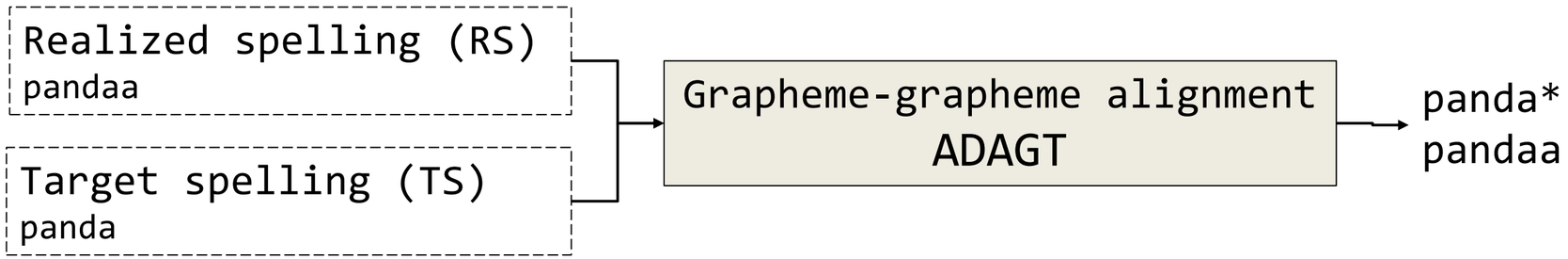

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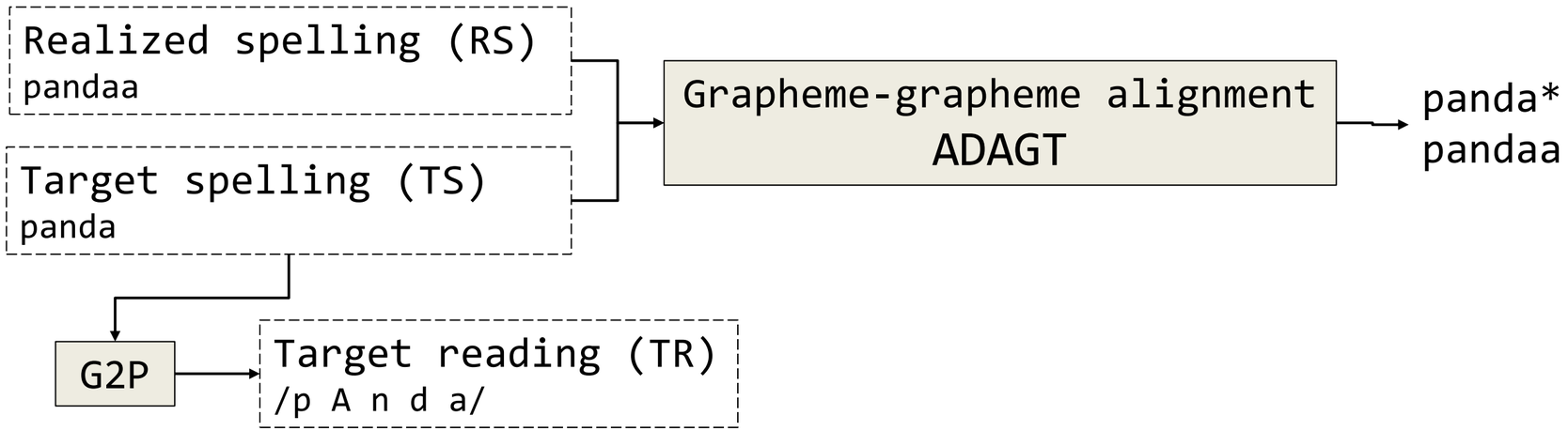

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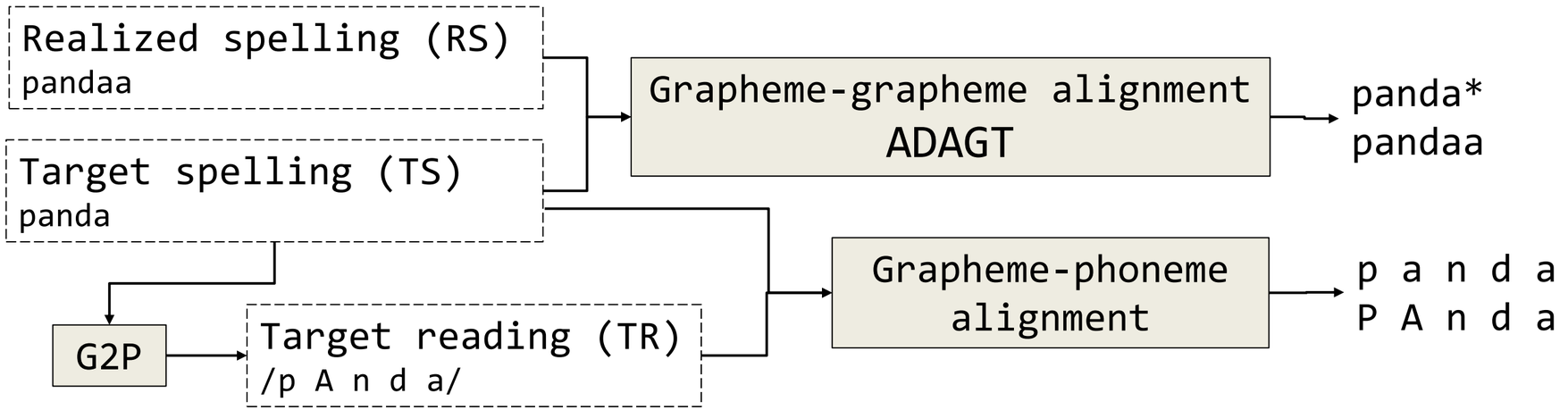

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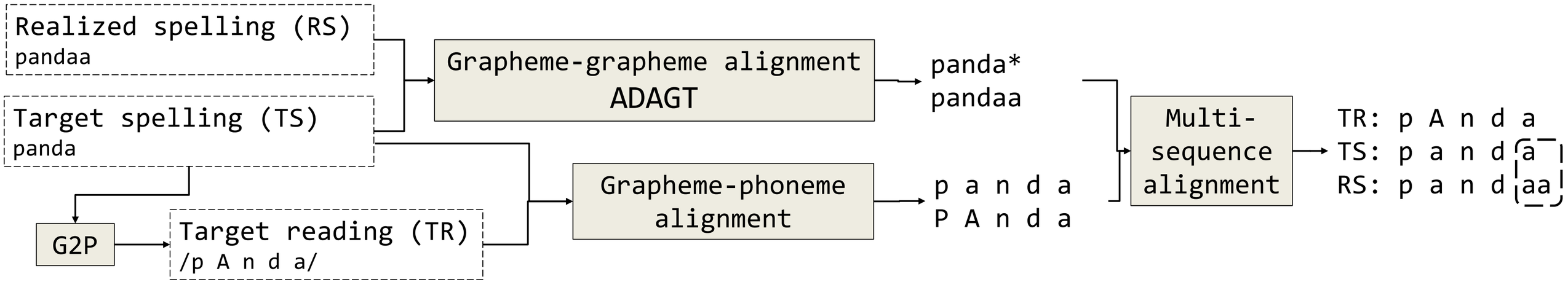

Method: Automatic annotation of PCUs with spelling principles

- Obtain lemma, POS-tags and morphemes of target word (FROG, van den Bosch et al., 2007)

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- Obtain lemma, POS-tags and morphemes of target word (FROG, van den Bosch et al., 2007)
- Rule-based (Harmsen et al., 2021)

```
TR:/p    A    n    d    a /
TS: p    a    n    d    a
RS: p    a    n    d    aa
    Un1  Un1  Un1  Un1  CoVs
```

Apply the Marked by Context: Vowel Singulation rule

Apply an Unmarked primary Phoneme-to-Grapheme rule

Method: Automatic annotation of PCUs with spelling principles

```
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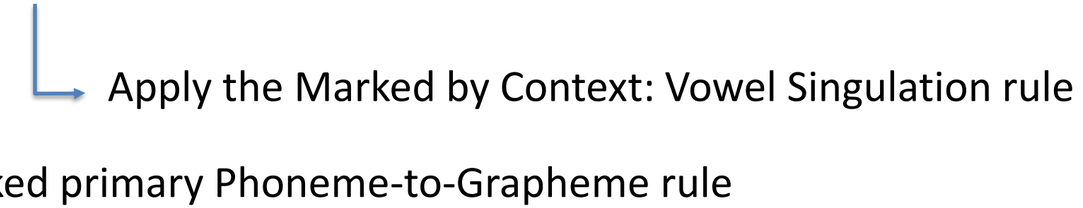


- The annotation scheme has three main categories (Horbach-Kleijnen, 1992):
  - **Unmarked (Un)** Apply phoneme-to-grapheme conversion rule
    - Un1 PCUs Only one way in which this phoneme can be written (e.g., /m/ -> m)
    - Un2 PCUs Multiple ways in which this phoneme can be written (e.g., /EI/ -> ei or ij; /x/ -> ch or g)
  - **Marked by Context (Co)** The context of a PCU influences the spelling
  - **Marked by Morphology (Mo)** The morpheme containing the PCU influences the spelling

Method: Extraction of measures using the annotated PCUs

- For **Marked by Context** and **Marked by Morphology**:
  - Divide the number of times a rule is applied incorrectly by the number of times the rule had to be applied in the dictation.
- For **Unmarked Rules**
  - Label each error with an error type:
    - Sub_mir The incorrectly written PCU is a mirrored version of the target PCU (e.g., b-d-p; w-m).
    - Sub_rev The incorrectly written PCU is a reversed version of the target PCU (e.g., oe -> eo; ui -> iu).
    - Sub_pho The incorrectly written PCU maps to the same phoneme as the target PCU.
    - Sub_oth The incorrectly written PCU maps to another phoneme than the target PCU.
  - Divide the number of errors in each error type by either the number of Un1 PCUs or the number of Un2 PCUs.

Method: Data analysis

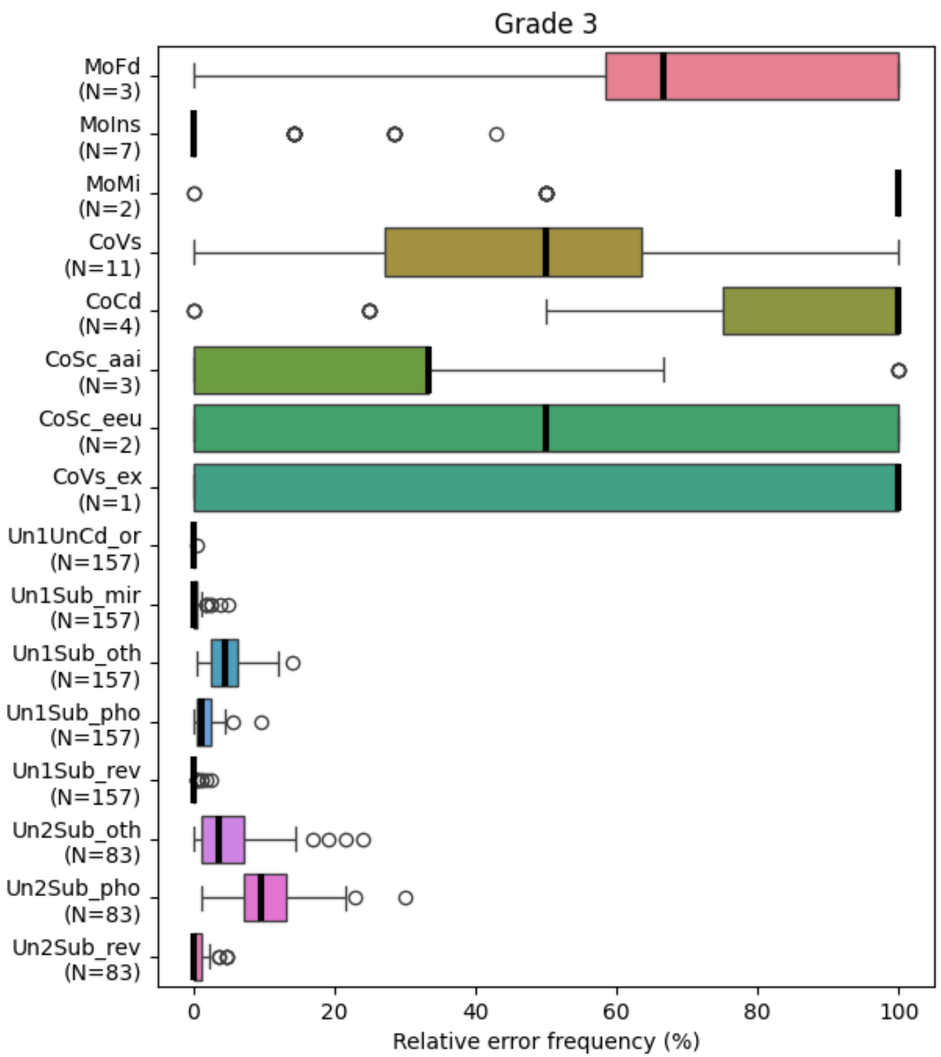
- Boxplots to visualize the performance on each spelling principle
- Hierarchical clustering
- Principle Component Analysis (PCA) to visualize clusters and identify differences between pupils.

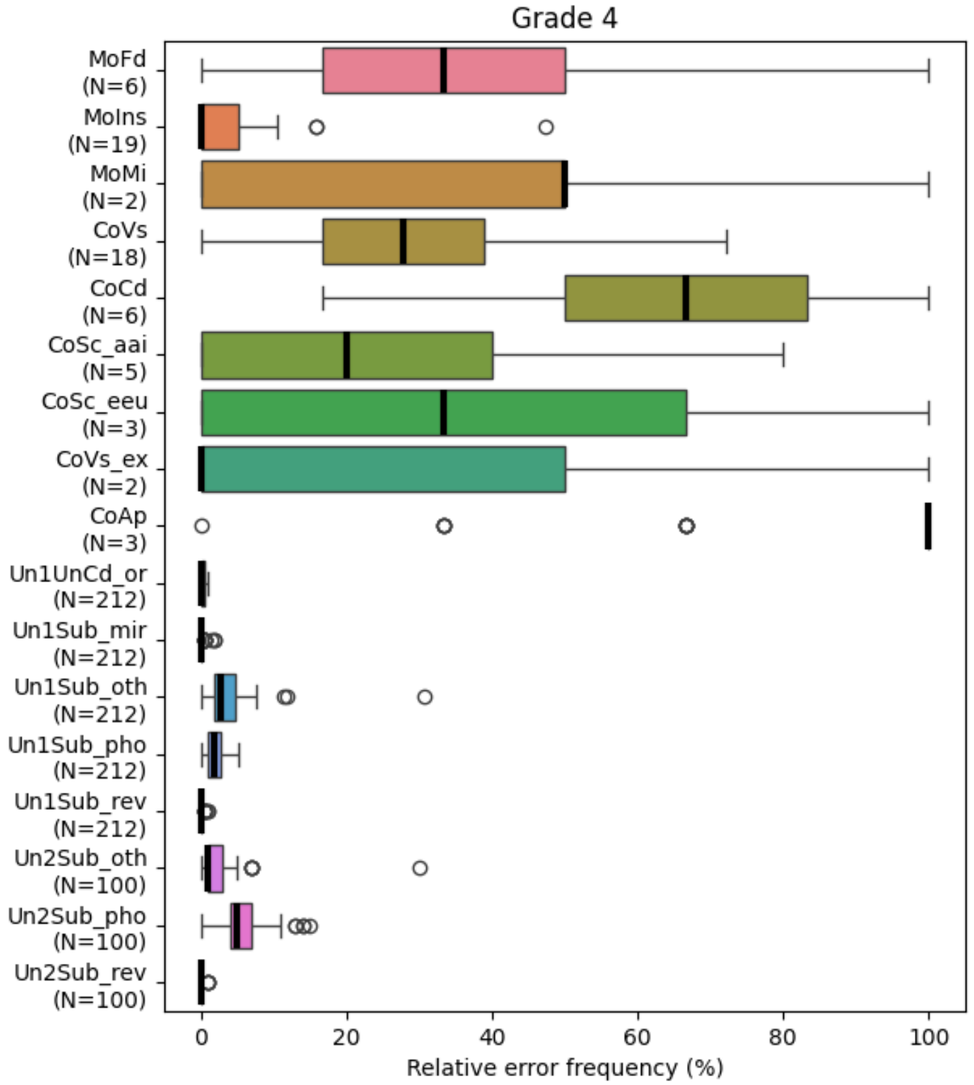
Results: Description of the data

grade	period	nr dictations	spelling score	
			mean	std
3	1	76	43.07	15.21
	2	60	56.40	16.23
	3	22	64.75	12.33
4	1	61	58.42	11.98
	2	52	68.46	13.73
	3	14	76.06	9.32

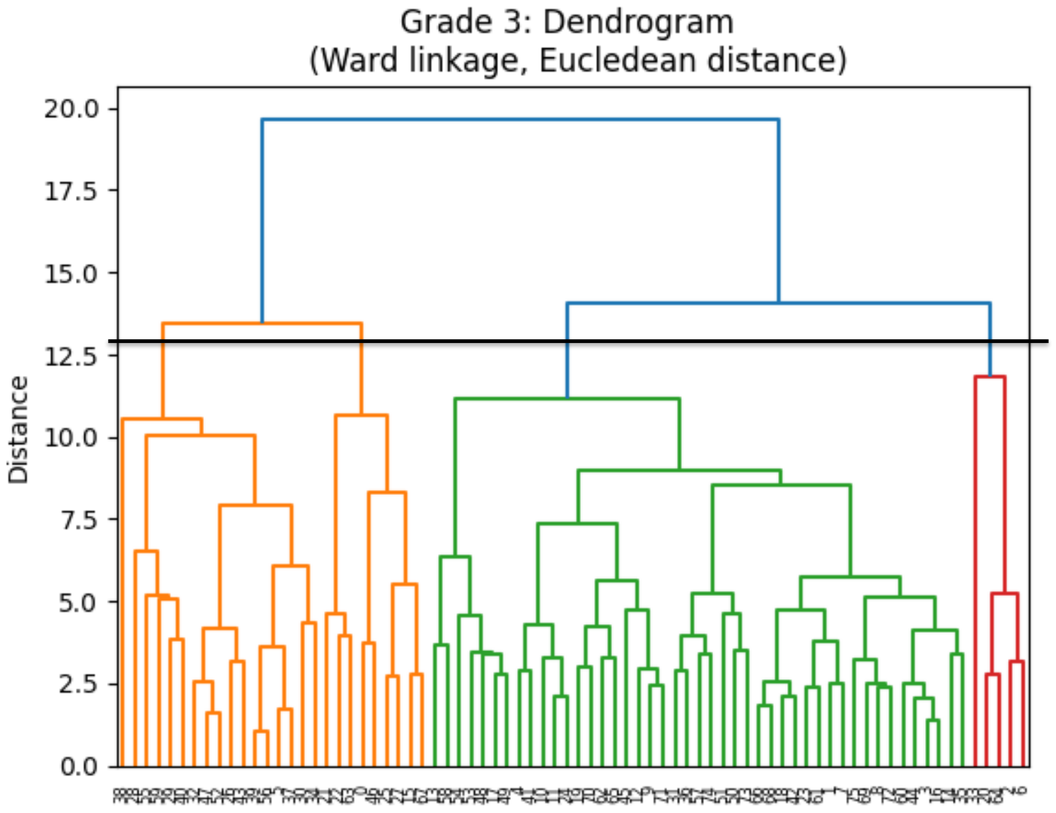
- Spelling score = percentage of correctly spelled words in dictation
- Not all children participated in all periods.
- On average, children become better spellers

Results: Proficiency in spelling error application

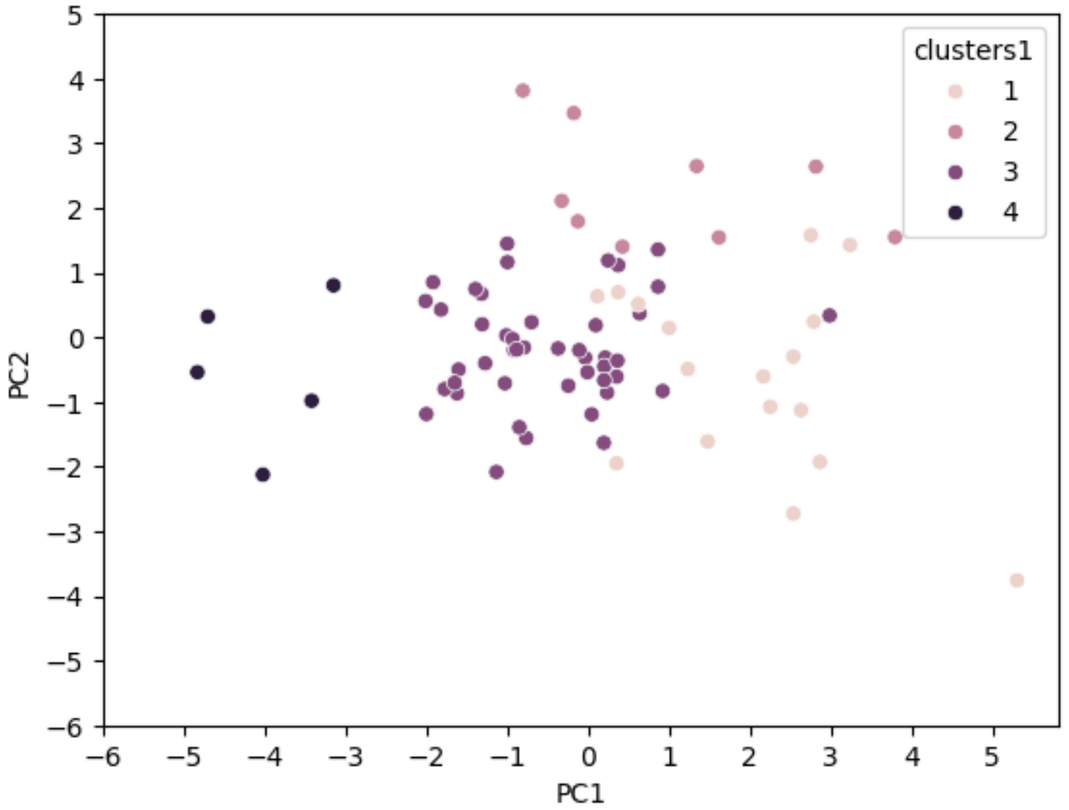




Clustering Grade 3



CoVs



Un2Sub_pho

Clustering Grade 4

- No clear clusters identified using the current method.

Discussion

RQ1: To what extent can we automatically measure children's ability to apply spelling principles?

- We presented a set of relative measures that quantify how often a spelling principle was applied incorrectly relative to the number of times a spelling principle had to be applied.
- Limitation:
  - Some spelling principles had to be applied only 1 or 2 times in the dictation. This is too little to measure a child's proficiency in applying this principle.

RQ2: What are problematic spelling principles for below-average Dutch spellers?

  - Grade 3: Consonant doubling (CoCd) rule -> ki**pp**en (*chickens*)
  - Grade 4: Apostrophe (CoAp) rule -> menu**'s** (*menus*)

Discussion

RQ3: Can we divide a group of below-average spellers into clusters based on their performance on specific spelling principles?

- Grade 3: Four clusters that differed on:
  - **Un2Sub_pho**: The percentage of phonetically correct errors made in PCUs that are phonetically ambiguous (e.g., writing *s**ch**ool* as *s**g**ool* (school))
  - **CoVs**: The percentage of incorrectly written PCUs where a vowel singulation rule had to be applied (e.g., writing *maken* as *maaken* (to make))
- Grade 4:
  - No clear clusters identified using the current measures and method
  - Future direction: Group the current measures differently

Conclusion

- First step towards obtaining more detailed information from children’s dictations
- Automatic evaluation of children’s ability to apply spelling principles
- This information can help teachers to personalize their instruction

Thank you!

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Tools: https://github.com/WiekeHarmsen/multi_seq_align_nl

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