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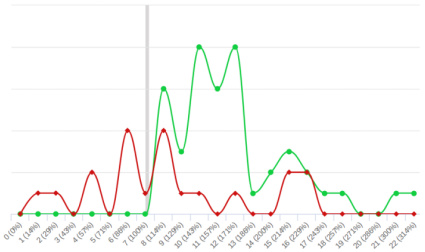
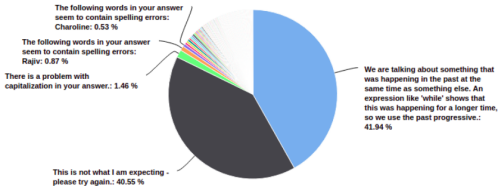
Adaptive systems for real-life education need explicit domain and activity models

and ways to generate them automatically





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Motivation: Addressing real-life education needs

- Learners differ substantially in:
  - subject domain knowledge
  - cognitive and motivational characteristics
  - academic language competencies
  - social support
  - ...

$\Rightarrow$ Materials, learning tasks, support and time should be adapted to the individual learner's abilities and needs.

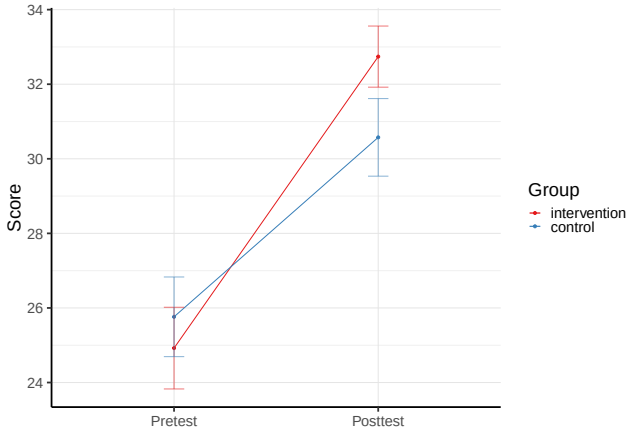
Adaptivity of two types

- Learning is optimal when it is **scaffolded** in the individual **Zone of Proximal Development** (Vygotsky 1986)
  - → supportive feedback while working on a task: **micro-adaptivity**
  - → adaptive selection of learning materials and tasks: **macro-adaptivity**
- Currently, such adaptivity cannot realistically be provided by teachers (lack of time, diagnostics, adaptive materials).
- Digital tools can support teachers by
  - providing micro- and macro-adaptivity to individual learners
  - informing teachers with individual/aggregated student information

Is micro-adaptivity effective?

- Feedback in general known to be effective (Hattie and Timperley 2007)
- How about specific, scaffolded feedback?
  - field study with 12 classes for entire school year (Meurers et al. 2019)
  - regular 7^{th} grade English classes, but using Intelligent Tutoring System FeedBook instead of traditional, printed work book
  - specific vs. true/false feedback for different grammar topics

  $\Rightarrow$ 63% higher learning gains for specific, scaffolded feedback:



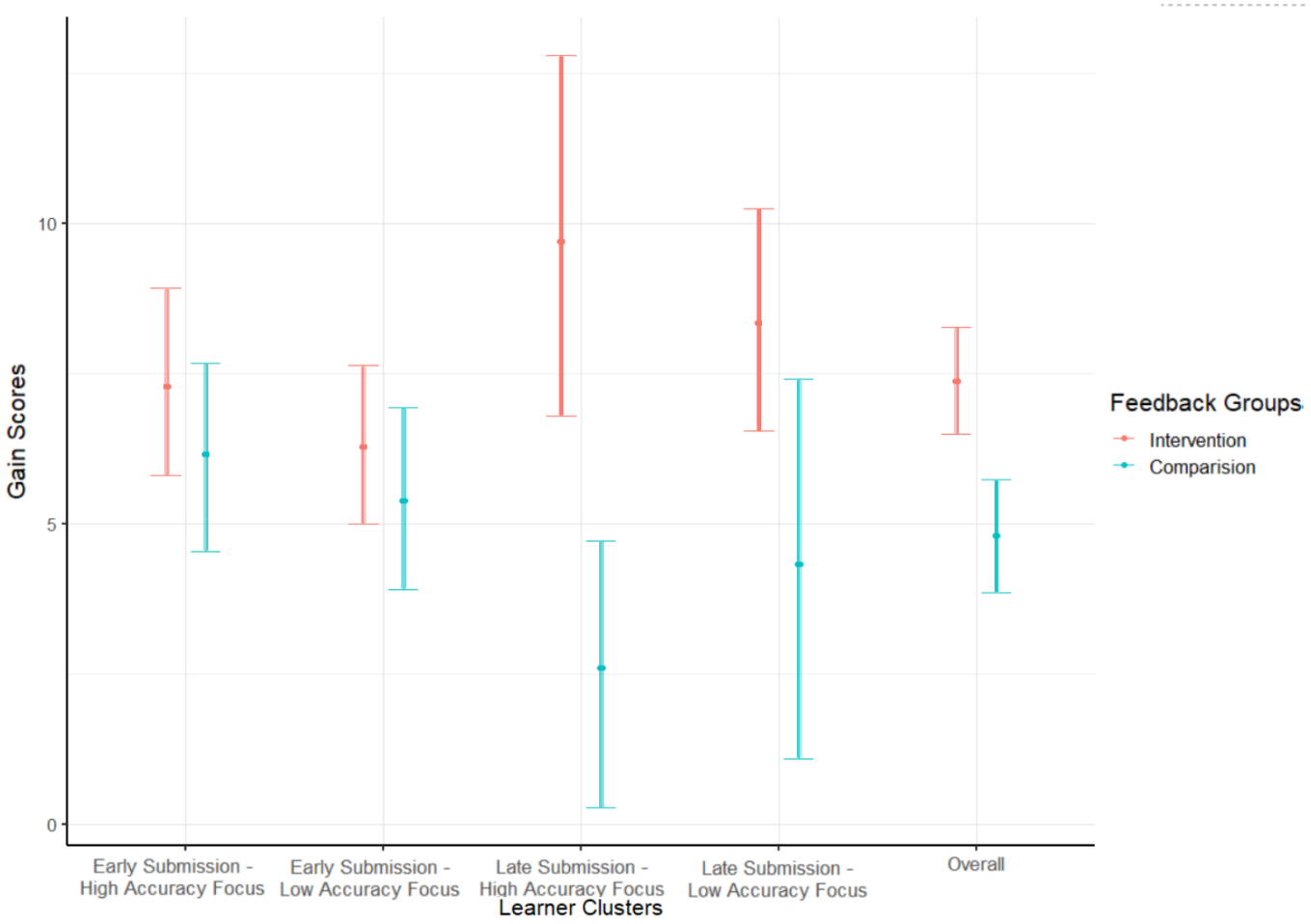
Effect size:
Cohen's d = 0.56

For whom is micro-adaptivity effective?

- How are learning gains and interaction patterns linked?
  $\rightarrow$ Learning analytics (Hui, Rudzewitz, and Meurers in press)
- Four groups of students, based on:
  - +/- accuracy focus of student
    How many of the items were filled out correctly, not left empty, answered correctly at first try?
  - +/- submission time of student relative to peers

$\Rightarrow$ Scaffolded feedback has the biggest effect for students who
- systematically attempt to solve the exercises correctly
- submit later than their peers

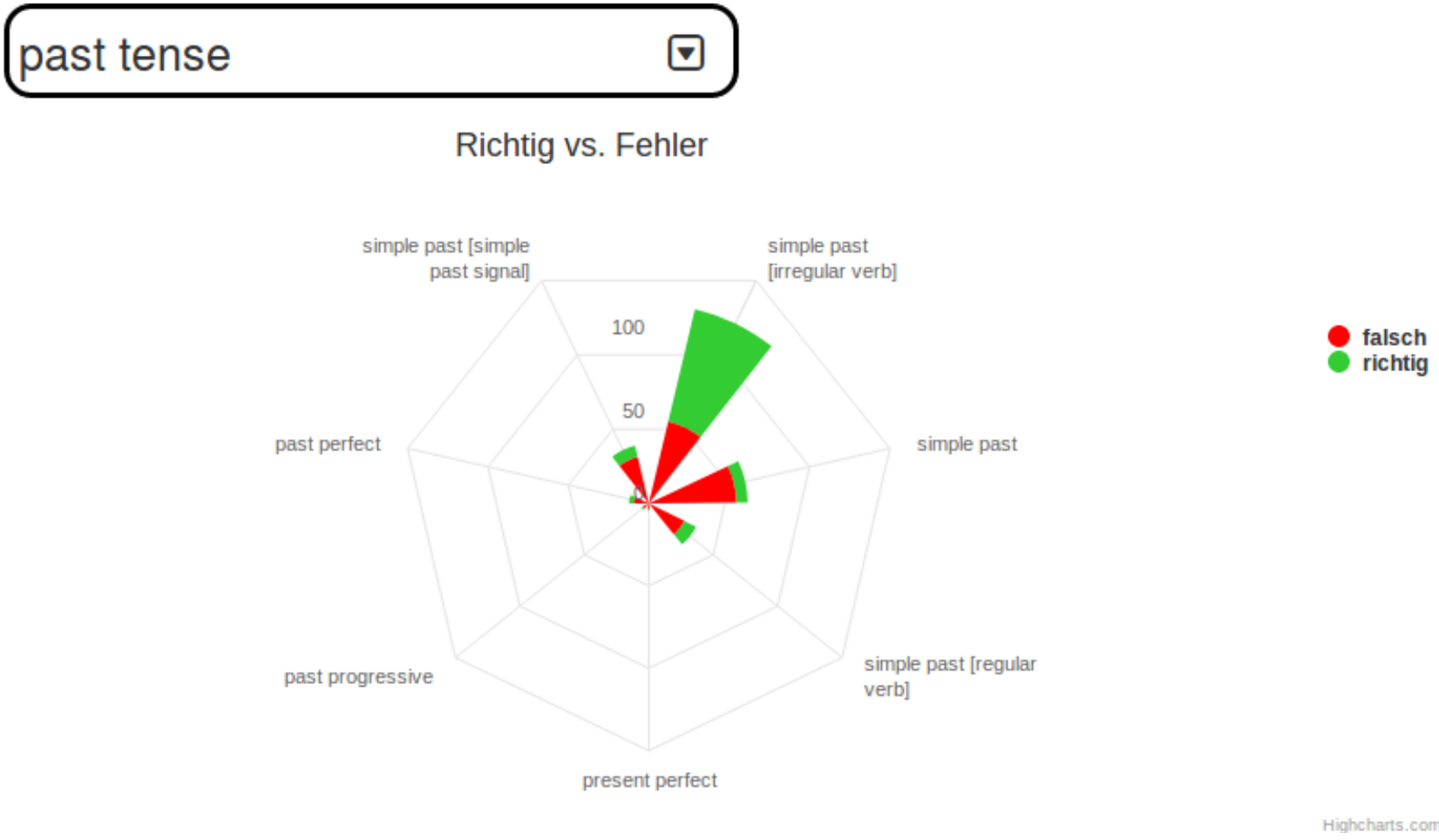
Who benefits most from the specific feedback?



Macro-adaptivity: components required for sequencing

- rich **learner model**: reflecting learner differences
  - exposure to constructs, in relation to **domain model**
  - accuracy of construct usage
  - cognitive characteristics
- rich set of **activities** and **activity models**:
  - learning opportunities offered by exercise
  - prerequisites for tackling exercise

Learner model: What do I know so far?



Learner model: What should I practice next?

Adapting learning paths for individual learners

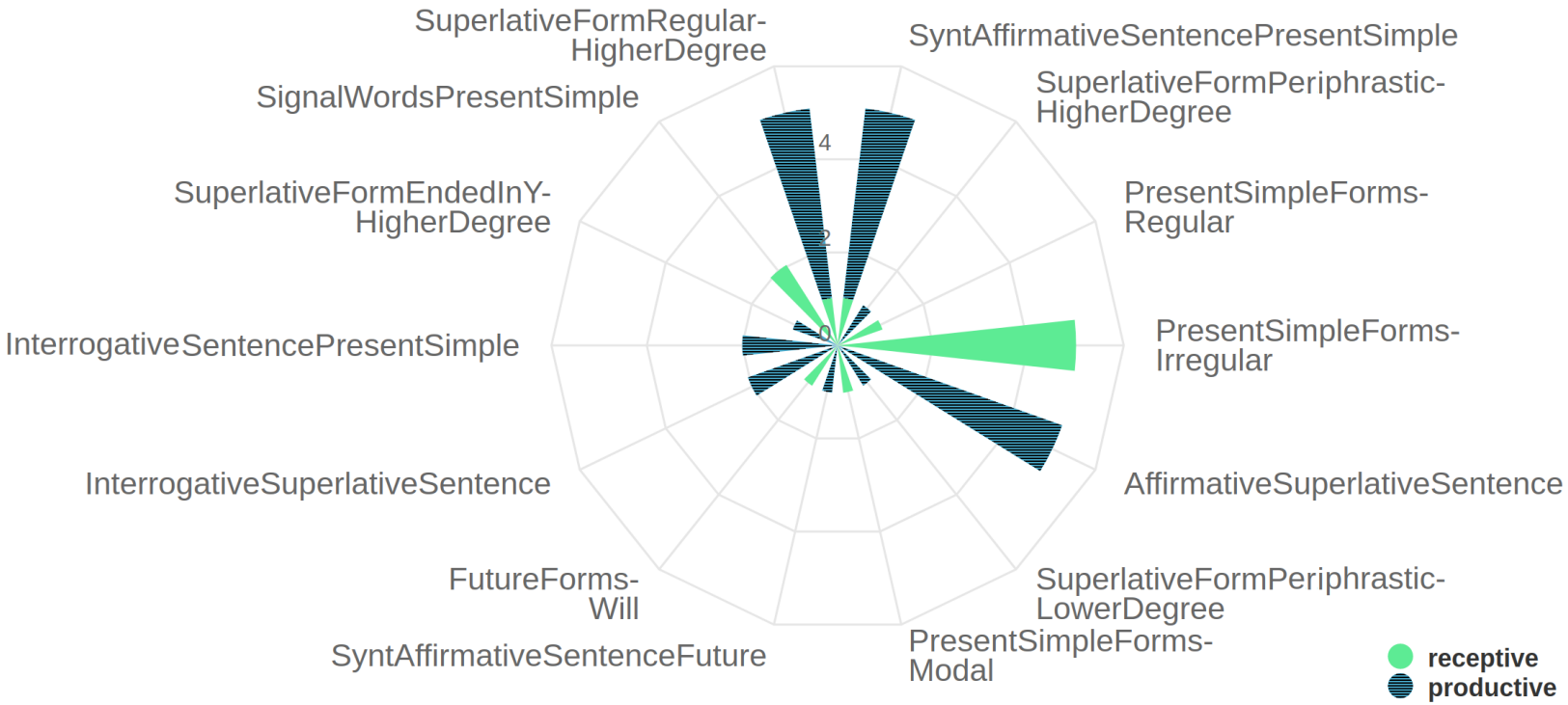
- Macro-adaptivity in the DiDi-FeedBook takes into account:
  - learner model: what has been learned so far
  - current executive functions ability, through fully integrated short game
- Activities differ in terms of:
  - complexity of language means to be practiced
  - complexity of language co-material in activity
  - activity type: memory, multiple-choice (2, 4), fill-in-blank (word, sentence)
  - scaffolding provided in activity (e.g., lemmas shown, adjacent or globally)
- Obtaining all these activities and activity models for such a rich space only feasible when generated automatically, e.g.
  - relative clauses: 19 exercises from single specification
  - conditional sentences: 48 exercises per specification

Generating activity models using NLP

(Quixal, Rudzewitz, Bear, and Meurers 2021)

- Activity specification:
  - Targeted language means (according to curriculum)
  - Activity type, language Input, instruction given to student
- Natural Language Processing then can be used to automatically:
  - determine specific subtypes of targeted language means (e.g., subject relative clauses with *who*)
  - non-target language means used in language material
  - skill: receptive or productive
  - supports adaptivity and facilitates alignment with standards (e.g., Cambridge English Grammar Profile)

Activity model derived for example activities



Adaptive sequencing

- Goal: link activity & learner models
- For language topic selected by learner as target, the system
  1. determines learner's mastery of target learning goals and prerequisites
     - sufficient practice opportunities & accuracy
  2. rank exercises by linguistic affinity score
     - compute fit between current learning goals and exercise
  3. rank exercises by pedagogical criteria
     - three learning phases: from closed to more open activities
- Working memory measure compared to median of all learners
  - easier exercise variants if below median, otherwise harder variant

→ Field study comparing adaptive sequencing to default sequence

Summing up

- Teachers need support for heterogeneous student groups.
- Adaptive digital tools can facilitate individualized practice in a student's Zone of Proximal Development.
  - micro-adaptive: scaffold a learning step
  - macro-adaptive: individual learning paths
- Adaptivity requires explicit learner, domain and activity models.
  - should take different dimensions of individual differences into account:
  - reducing adaptivity to speed (e.g., skipping steps) does not do justice to multidimensional nature of student heterogeneity and learning tasks
- To adaptively support learning, richly parameterized sets of learning tasks corresponding to learner heterogeneity are needed.
  - can be facilitated by automatic activity and activity model generation

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