This Talk

• How to conceptualize AI in relation to human learning?

• Theoretical Framing

• Empirical underlayers
  - Measurement of SRL
  - Support of SRL

• Toward Hybrid Human-AI Regulation
WHY: Onload Regulation

1. Deep Learning
2. Future learning
Concept: Hybrid Human-AI Regulation
Hybrid Human-AI Regulation: Transfer of Control
The overall objective is to design, develop and evaluate Hybrid Human-AI Regulation (HHAIR) to support young learners’ deep and future learning in the context of ALTs.
Context: Adaptive Learning Technologies
Theoretical Framing

SRL

LA

AI
Theoretical Framing: Self-Regulated Learning

Cognition

Motivation

Emotion

Metacognition

SRL

(Greene & Azevedo, 2010)
Theoretical Framing: The COPES Model

(Winne & Hadwin, 1998; Panadero et al. 2018)
Theoretical Framing: Learning Analytics

- *extracted analytics*, in the form of learner dashboards to explain to learners how to regulate their learning;

- *embedded analytics*, in the form of advanced algorithms to detect learners’ SRL and perform AI-regulation.

- Agency over regulation is gradually transferred from AI to learners, who increasingly becomes more responsible for and active in his/her own regulation.
Challenges

1. Measurement: Identify individual learner’s SRL during learning

2. Support: Design Hybrid Human-AI Regulation

3. Evaluate effectiveness
   a) optimizing deep learning
   b) for future learning
Traditional measurement SRL

Self-report

Think-aloud
Multimodal Measurements of SRL

- Logs
- Physiological data
- Video
- Voice
- Keyboard & mouse
- Eye tracking
Measurement of SRL in the context of ALTs

Logs

Knowledge model

Adaptive Learning Lab (ALL)
Empirical work on Measurement
Moment-by-Moment Learning Curves

- Moment-by-moment learning curves show the probability ($P(J)$) a student learned at each practice opportunity for a specific skill (Baker et al. 2013)
- Indicates gradual vs. sudden learning: spikes show shifts in performance
- Research indicated that spikiness of ($P(J)$) is associated with learning (Baker & Goldstein, 2010; 2011)
- 7 Visual patterns were found which were related to different learning outcomes (Baker et al. 2013)
  - immediate peak curves were correlated with retention
  - immediate drop curves were associated with post-test scores
Method

Sample:
- 95 students in grade 5, 4 classes in 4 schools
- 51 boys and 44 girls, average aged 10.88
- 265 curves were used in the analysis
  - curves with less than 15 problem solving attempts were not included
# Measurements

<table>
<thead>
<tr>
<th>Learning measures</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior knowledge</td>
<td>Pre-test, 8 items per subskill</td>
</tr>
<tr>
<td>Post Knowledge</td>
<td>Post-test, 8 items subskill</td>
</tr>
<tr>
<td>Gain</td>
<td>Post-test - pre-test per subskill</td>
</tr>
<tr>
<td>Transfer</td>
<td>15 items test</td>
</tr>
<tr>
<td>Process measures</td>
<td>Log file data</td>
</tr>
<tr>
<td>Effort</td>
<td>Number of unique problems completed per subskill</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Correct unique problems / total unique problems completed</td>
</tr>
</tbody>
</table>
Moments-by-Moments Learning Curves

66 Immediate Drop 25%

118 Immediate Peak 45%

35 Close multiple spikes 13%

46 Separate multiple spikes 17%
Associations with Accuracy

- Immediate drop
- Immediate peak
- Close multiple spikes
- Separate multiple spikes

Accuracy problems and accuracy attempts with associated significance levels (*).
Associations with learning

- Immediate drop
- Immediate peak
- Close multiple spikes
- Separate multiple spikes

Score:
- Pre-test
- Post-test
- Gain
- Transfer

Grafiekgebied

Radboud University
## MbML in light of SRL

<table>
<thead>
<tr>
<th></th>
<th>Student learning</th>
<th>Student regulation</th>
<th>Human-AI regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate drop</td>
<td>Low gain, high transfer</td>
<td>High accuracy</td>
<td>Inefficient learning &amp; regulation</td>
</tr>
<tr>
<td>Immediate peak</td>
<td>High gain and transfer</td>
<td>Relatively high accuracy</td>
<td>Efficient learning &amp; regulation</td>
</tr>
<tr>
<td>Close separate spikes</td>
<td>Moderate gain and relatively high transfer</td>
<td>Reduced accuracy</td>
<td>Moderate learning &amp; challenges in regulation</td>
</tr>
<tr>
<td>Multiple separate spikes</td>
<td>Moderate gain and low transfer</td>
<td>Strongly reduced accuracy</td>
<td>Reduced learning &amp; ineffective regulation</td>
</tr>
</tbody>
</table>

MbMLC & phases in the classroom
MbMLC and peaks in learning phases

- separate multiple spike
- close multiple spike
- double spike
- immediate peak
- immediate drop

Legend:
- pre-test
- guided-practice
- non-adaptive practice
- adaptive practice
- repeated adaptive practice
- post-test
### Need for SRL support

<table>
<thead>
<tr>
<th>Groups</th>
<th>MbMLC curves</th>
<th>Support</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SRL group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Immediate drop</td>
<td>• Reduce teacher and system regulation</td>
</tr>
<tr>
<td></td>
<td>Immediate peak</td>
<td>• Students may benefit from learner-dashboards</td>
</tr>
<tr>
<td><strong>Teacher regulation group</strong></td>
<td>Immediate peak</td>
<td>• Continue teacher regulation</td>
</tr>
<tr>
<td></td>
<td>Double Spikes</td>
<td>• Students may benefit from learner-dashboards to improve SRL</td>
</tr>
<tr>
<td></td>
<td>Close multiple spikes</td>
<td></td>
</tr>
<tr>
<td><strong>System regulation group</strong></td>
<td>Close multiple spikes</td>
<td>• Continue teacher and system regulation</td>
</tr>
<tr>
<td><strong>Advanced system regulation group</strong></td>
<td>Separate multiple spikes</td>
<td>• Advanced system support</td>
</tr>
</tbody>
</table>

Support: Personalized Dashboards
Designing theory grounded support

<table>
<thead>
<tr>
<th>Degrees</th>
<th>AI</th>
<th>Human</th>
<th>Function Dashboard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Regulation</td>
<td>Observes regulation</td>
<td>self-initiation of control</td>
<td>Mirror regulation</td>
</tr>
<tr>
<td>Shared-Regulation</td>
<td>Monitors &amp; proposes control</td>
<td>Understands enactment of control</td>
<td>Scaffold enactment of control</td>
</tr>
<tr>
<td>Co-Regulation</td>
<td>Monitors &amp; Controls</td>
<td>Understands how AI monitors</td>
<td>Model AI monitoring and control</td>
</tr>
<tr>
<td>AI Regulation</td>
<td>Monitors &amp; Controls</td>
<td>Aware of AI regulation</td>
<td>Raise awareness</td>
</tr>
</tbody>
</table>
The design of the Learning Path App

Winne & Hadwin, 1998;2013)
Task Definition Phase: Overview Screen
Goal Setting Phase: Goal Setting Screen

Calculate capacity using the formula: ‘capacity = length x width x height’

Ultimate goal:
- 0% to 50% completed
- 50% to 100% goal

Goal after the first lesson:
- 0% to 50% completed
- 50% to 100% goal

Goal after the repetition lesson:
- 0% to 50% completed
- 50% to 100% goal
Enactment Phase: Overview Screen
Adaptation Phase: Learning Path Screen

(Molenaar, Horvers & Baker, 2020)
Posters

Leerpaden app

**Eerste les**

**Overzichtsscherm**
- De nummers in de doffijn zijn de leenbeukjes.
- Keur van de doffijn.
- Grijp je hebt nog geen doel gesteld.

→ Klik op de doffijn om je doel te stellen.

**Doel zetten scherm**

Stel je doelen:
- *Enkel* doe je voor denk je dat je kunt komen op dit leenbeukje?
- *Pirat* hoe ver denk je dat je kunt komen na de Pirat?

Keer van de vliegenpils:
- Grijp je hebt nog geen doel gesteld.
- Klik je hebt een doel gesteld, maar het nog niet behaald.

---

**Verder werken met Leerpaden app**

**Overzichtsscherm**

Er staat van de doffijn:
- Klein, je hebt nog weinig groefend op dit leenbeukje.
- Grof, je hebt al veel groefend op dit leenbeukje.

Plak je de doffijn:
- Rechts je moet nog meer zelfwenn op dit leenbeukje.
- Links, je bent groefend op dit leenbeukje.

Keer van de doffijn:
- Groen, je hebt je doel behaald.
- Oranje, je hebt je doel nog niet behaald.
- Grijp je hebt nog geen doel gesteld → klik op de doffijn om een doel te stellen.

→ Hoog, je hebt je doel voor na de Pirat behaald. Bel je hebt je doel voor na de Pirat behaald.

---

**Leerpaden app**

**Hoog zwemmer**
- Je kan het leerdoel al.
- Je werkt nauwkeurig, heel goed!
  - Kies een ander leerdoel om meer te oefenen.

**Snelle stijger**
- Je hebt snel gekeerd.
- Je werkt nauwkeurig, heel goed!
  - Kies een ander leerdoel om meer te oefenen.
  - Is je doelvijf groen?
    - Kies een ander leerdoel om meer te oefenen.
  - Is je doelvijf oranje?
    - Ga verder tot de doelfijn groen wordt.

**Langzame stijger**
- Je hebt geleerd na de opleiding van je pui of meester.
  - Zorg dat je nauwkeurig werkt!
  - Is je doelfijn groen?
    - Kies een ander leerdoel om meer te oefenen.
  - Is je doelfijn oranje?
    - Ga verder tot de doelfijn groen wordt.

**Laag zwemmer**
- Je bent langzaam aan het leren.
  - Stel vragen aan je pui of meester als je het niet weet.
  - Zorg dat je nauwkeurig werkt.

**Stijger en daler**
- Je bent langzaam aan het leren.
  - Stel vragen aan je pui of meester als je het niet weet.
  - Zorg dat je nauwkeurig werkt.
  - Ga verder tot de doelfijn groen wordt.

→ Probeer een andere stijger te worden!
Empirical work on Support
Design
Sample:
- 92 students in grade 5, 5 classes in 4 schools
- Experimental condition n=60 and control condition n=32
- Learners average ages 10.15 between 10 and 12 years old
- 38 boys and 54 girls
## Measurements

<table>
<thead>
<tr>
<th>Learning measures</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior knowledge</td>
<td>Pre-test, 8 items per subskill</td>
</tr>
<tr>
<td>Post Knowledge</td>
<td>Post-test, 8 items subskill</td>
</tr>
<tr>
<td>Gain</td>
<td>Post-test - pre-test per subskill</td>
</tr>
<tr>
<td>Transfer</td>
<td>15 items test</td>
</tr>
<tr>
<td>Process measures</td>
<td>Log file data</td>
</tr>
<tr>
<td>Effort</td>
<td>Number of unique problems completed per subskill</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Correct unique problems / total unique problems completed</td>
</tr>
</tbody>
</table>
Effects of Regulation of Practice Behavior

• Significant effect on accuracy $F(2, 85) = 4.88, \ p < 0.01$
• No effect of effort, $F(2, 85)= 1.62, \ p > 0.05$
• Improved practice behavior for skill 2 and 3
Effects on learning outcomes

Significant effect on transfer $t(85, 2) = 2.33, p < 0.05$
Effects on Monitoring Accuracy

![Bar chart showing the percentage of students overestimating, calibrating, and underestimating for different subskills between PV and control groups.](chart.png)
Towards Hybrid Human-AI Regulation
### Designing theory grounded support

<table>
<thead>
<tr>
<th>Degrees</th>
<th>AI</th>
<th>Human</th>
<th>Function Dashboard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Regulation</strong></td>
<td>Observes regulation</td>
<td>self-initiation of control</td>
<td>Mirror regulation</td>
</tr>
<tr>
<td><strong>Shared-Regulation</strong></td>
<td>Monitors &amp; proposes control</td>
<td>Understands enactment of control</td>
<td>Scaffold enactment of control</td>
</tr>
<tr>
<td><strong>Co-Regulation</strong></td>
<td>Monitors &amp; Controls</td>
<td>Understands how AI monitors</td>
<td>Model AI monitoring and control</td>
</tr>
<tr>
<td><strong>AI Regulation</strong></td>
<td>Monitors &amp; Controls</td>
<td>Aware of AI regulation</td>
<td>Raise awareness</td>
</tr>
</tbody>
</table>
Hybrid Human-AI Regulation

Task conditions: Cognitive conditions

Internal

Phase 1
Definition of Tasks

Phase 2
Goals & Plan(s)

Phase 3
Tactics & Strategies

Phase 4
Adaptations

Standards

Products

Products - Standards

Cognitive Evaluations

Small-scale adaptations

Large-scale adaptations

MONITORING

CONTROL

External

Self-regulation

To be developed

To be developed

To be developed

To be developed

To be developed

Shared regulation

To be developed

To be developed

To be developed

To be developed

Co-regulation

AI regulation

To be developed

To be developed

To be developed

To be developed

External Evaluations

Behavioural Science Institute
Adaptive Learning Lab (ALL)
Radboud University
Hybrid Human-AI Regulation: Transfer of Control
Would you like to read more?

| --- |
Want to work with us?

- We are looking for
  - A Post-Doc with a strong AI background
  - A Post-Doc combining educational insights with LA and AI

- This Spring:
  - PhD for designing teacher Dashboards
  - PhD for measuring and supporting SRL in Secondary Education
Thank you for your attention

Inge.Molenaar@ru.nl