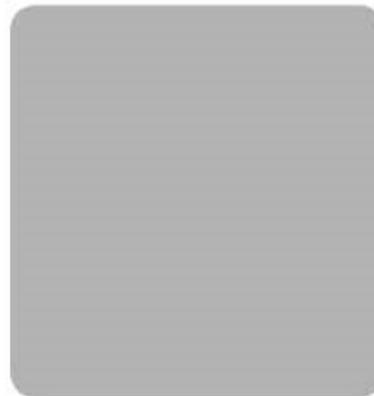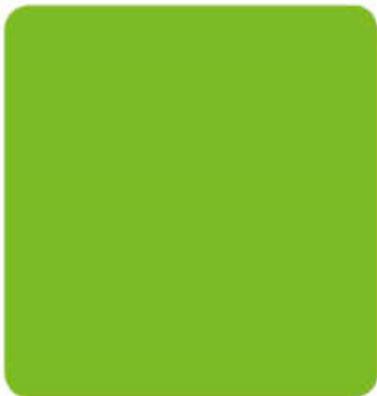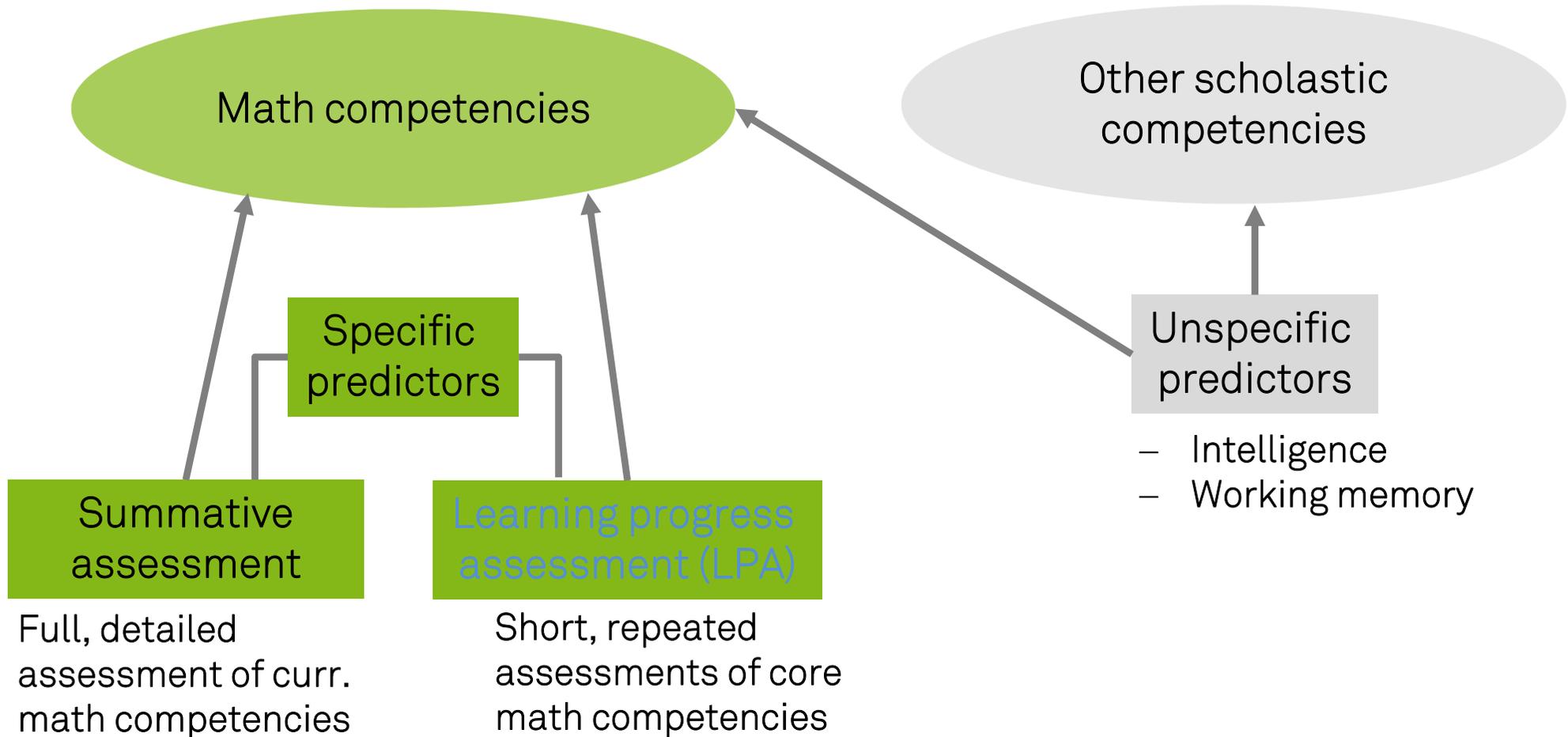# Learning progress assessment in mathematics: Psychometric properties and relation to summative predictors of mathematical skills

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Background

Math competencies

Other scholastic
competencies

Specific
predictors

Unspecific
predictors

Summative
assessment

Learning progress
assessment (LPA)

Full, detailed
assessment of curr.
math competencies

Short, repeated
assessments of core
math competencies

− Intelligence
− Working memory

Overview

1. Psychometric properties of LPA
   (Schwenk, Chromik, Doebler, & Kuhn, in Rev.)

2. Predictive utility of LPA in classroom setting
   (Kuhn, Schwenk, Souvignier, & Holling, 2019)

3. Predictive utility of LPA in (field) intervention setting
   (Schwenk, Kuhn, Gühne, Doebler, & Holling, 2017)

1. Psychometric properties of LPA: Assessment

- LVD-M 2-4 (Lernverlaufsdiagnostik Mathematik; Strathmann & Klauer, 2012): Curriculum-based P&P test, 24 items (mental and written calculation)

Item(s)	Task structure	Place value structure/ arithmetic operator	Mode	Example
1-2	a + b = ?	HTO + TO (with T+T < 100)	m	926 + 53 = ?
3	c – b = ?	HTO – O (with ? > H, first O < second O)	m	982 – 3 = ?
4	c – b = ?	HTO – HTO	m	856 – 117 = ?

…
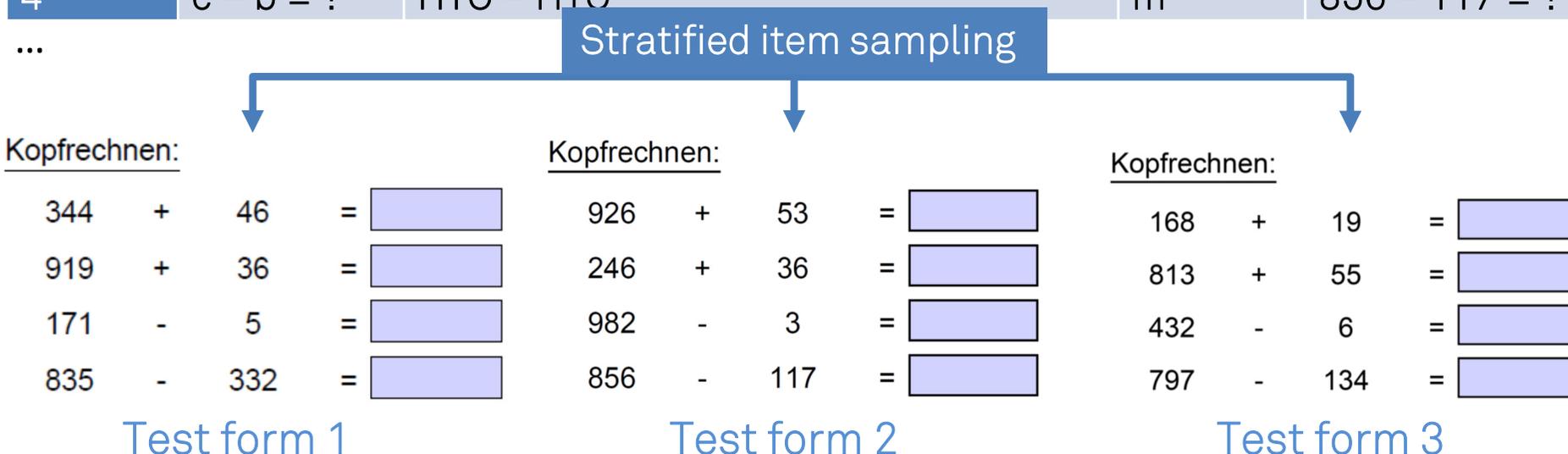
1. Psychometric properties of LPA: Design

- **Does the booklet equivalence assumption hold?**

- Administration of 10 different test forms of LVD-M, approx. 2 weeks apart

- Sample: Elementary school children (N = 109 third grade/42.7% girls, N = 108 fourth grade/45% girls)

- Latin square design of test forms

Measurements 1-10 / Booklet versions A-J												
	1	2	3	4	5	Easter break	6	7	8	9	10
Order	Jan	Jan	Feb	Feb	Mar		Apr	Apr	May	May	Jun
1	A	B	C	D	E		F	G	H	I	J
2	B	C	D	E	F		G	H	I	J	A
3	C	D	E	F	G	Feed-back	H	I	J	A	B
...											
9	I	J	A	B	C		D	E	F	G	H
10	J	A	B	C	D		E	F	G	H	I

1. Psychometric properties of LPA: Analysis

- Estimation of a linear mixed model

$$y_{ijkt} = \beta_0 + b_{0k} + b_{0j} + b_{0i|j} + (\beta_1 + b_{1j} + b_{1i|j}) \times time_t + s_{ijkt}$$

- y_{ijkt} = Total test score of
  - individual i
  - in classroom j
  - at time t
  - completing booklet k

Parameter	Meaning
β_0	Fixed intercept
β_1	Fixed slope
b_{0k}	Random intercept booklet
b_{0j}	Random intercept classroom
$b_{0i|j}$	Random intercept individual
b_{1j}	Random slope classroom
$b_{1i|j}$	Random slope individual

1. Psychometric properties of LPA: Results

Level	Parameter	Grade 3 ($n = 108$)	Grade 4 ($n = 109$)
fixed effects			
	β_0	15.38 (0.54)	9.31 (0.47)
	β_1	0.18 (0.15)	0.27 (0.12)
random effects			
booklet	$\mathrm{var}(b_{0k})$	0.25	0.28
class	$\mathrm{var}(b_{0j})$	0.16	0.59
class	$\mathrm{var}(b_{1j})$	0.20	0.11
class	$\mathrm{cor}(b_{0j}, b_{1j})$	.45	.55
individual	$\mathrm{var}(b_{0ilj})$	25.72	13.80
individual	$\mathrm{var}(b_{1ilj})$	0.22	0.23
individual	$\mathrm{cor}(b_{0ilj}, b_{1ilj})$	-.61	-.43
individual	$\mathrm{var}(\text{Residual})$	18.67	9.41

2. Predictive utility of LPA in classroom setting: Design

N = 196 (3rd/4th grade, age: M = 8.62 years, 55% girls)

Specific assessment
- DEMAT — Arithmetics
- DIRG — Fact retrieval

Unspecific assessment
- CFT — Intelligence
- SLS — Reading fluency

LPA

LVD-M 2-4

10 measurements (2 weeks apart)
Individual intercept and slope (RE)

DEMAT — Arithmetics

Aug – Sep 2015   Jan – Jul 2016   Jun – Jul 2016
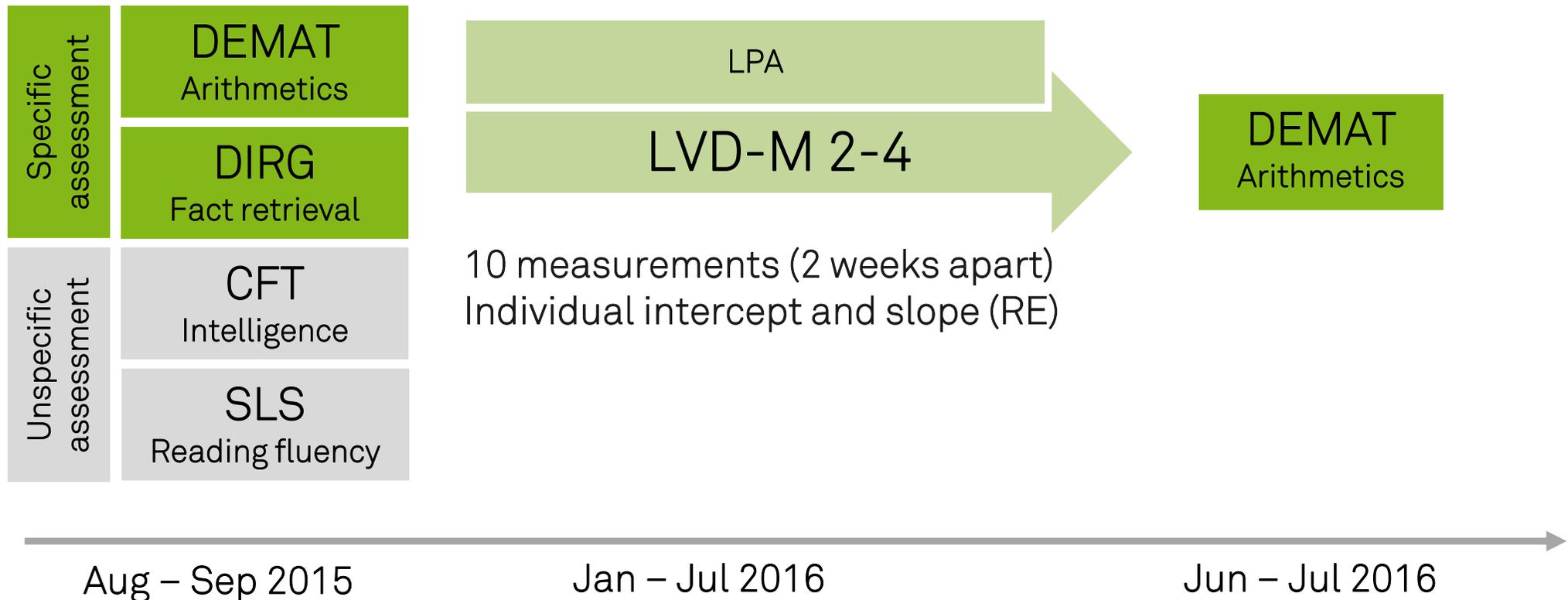
2. Predictive utility of LPA in classroom setting: Results

	Variable	Arithmetics (T2)		
		b	SE	t
U	Intelligence	.12	.06	2.06*
	Reading fluency	-.01	.06	-.18
S	Arithmetics (T1)	.23	.08	3.03**
	Fact retrieval	.09	.06	1.58
L	LVD-M Intercept	.57	.08	6.82**
	LVD-M Slope	.27	.05	5.01**

R^2 = .568

Relative importance
(Luo & Azen, 2013, JEBS)

L > S > U

.300   .197   .071

3. Predictive utility of LPA in (field) intervention setting: Intervention

„Feuergeister"

„Magische Zylinder"

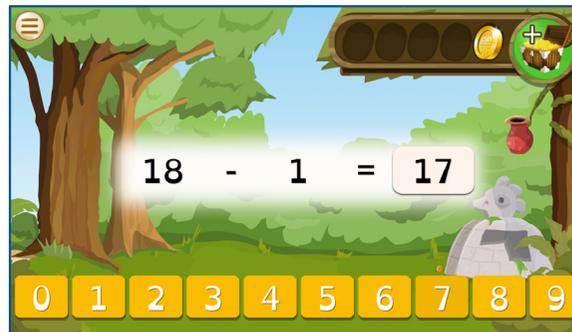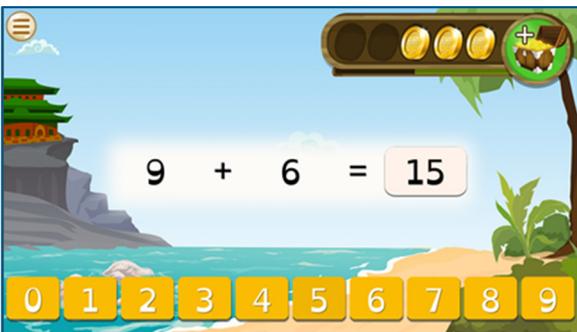# 3. Predictive utility of LPA in (field) intervention setting: LPA

Addition (90 sec)

Subtraction (90 sec)
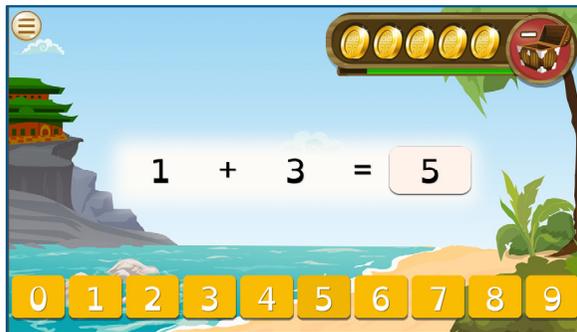
Number order (90 sec)


Without crossing tens boundary

With crossing tens boundary
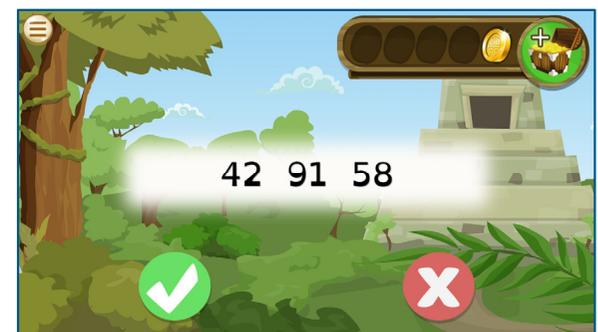
3. Predictive utility of LPA in (field) intervention setting: Design

- Design principle: *robust indicators,* items randomly drawn with constraints

- LPA was always administered after 5 training days

- High speed high stakes scoring (Klinkenberg et al., 2014)

Efficiency

Total group (*n* = 241)

ZO
Add
Sub

PR ≤ 25 (*n* = 65)

ZO
Add
Sub
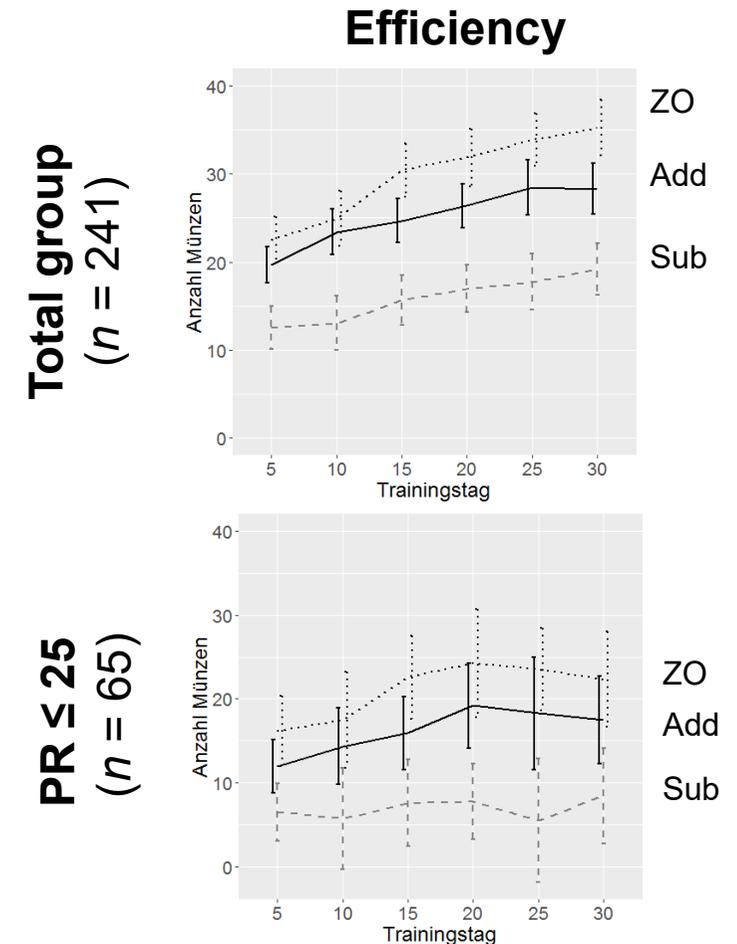
3. Predictive utility of LPA in (field) intervention setting: Results

- Reliability (split-half): $r = .87 - .93$, Validity: $r = .51$

- Sensitivity to change: Prediction of summative math assessment (CODY-M 2-4) after 30 days of training (CODY-M 2-4 posttest)

	Variable	b	SE	t
S	CODY-M 2-4 (pretest)	0.48***	0.09	5.64
L	Intercept LPA	0.13	0.09	1.43
	Slope LPA	0.18*	0.08	2.19

Note: $N = 127$ (both CODY-M 2-4 pretest and posttest), grades 2-4.
p < .05, ***p* < .001.

Key results

- Study 1: Stratified item sampling can create practically equivalent booklets → assumption of equivalent LPA booklets plausible

- Study 2: LPA is more predictive of math achievement than specific or unspecific predictors → LPA key predictor of math achievement in classroom setting

- Study 3: LPA predicts posttest math achievement beyond pretest achievement → LPA sensitive to intervention-induced change

What's next?

- How can we connect LPA and instructional decision-making more closely in digital environments?
  - Linking LPA, logged intervention data and adaptive algorithm more closely (individual learning trajectories, coachings, accuracy/response times)?
  - Learning networks?

- How can we identify responders and non-responders of interventions early in the process to adapt intervention?
  - Combining summative assessment and learning analytics?
  - Which statistical models are useful in small samples and single-case research designs?
  - Which intervention components are effective in a multicomponent intervention?

Thanks for your attention!

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