Executive Functions as Moderators of the Worked Example Effect: When Shifting Is More Important Than Working Memory Capacity

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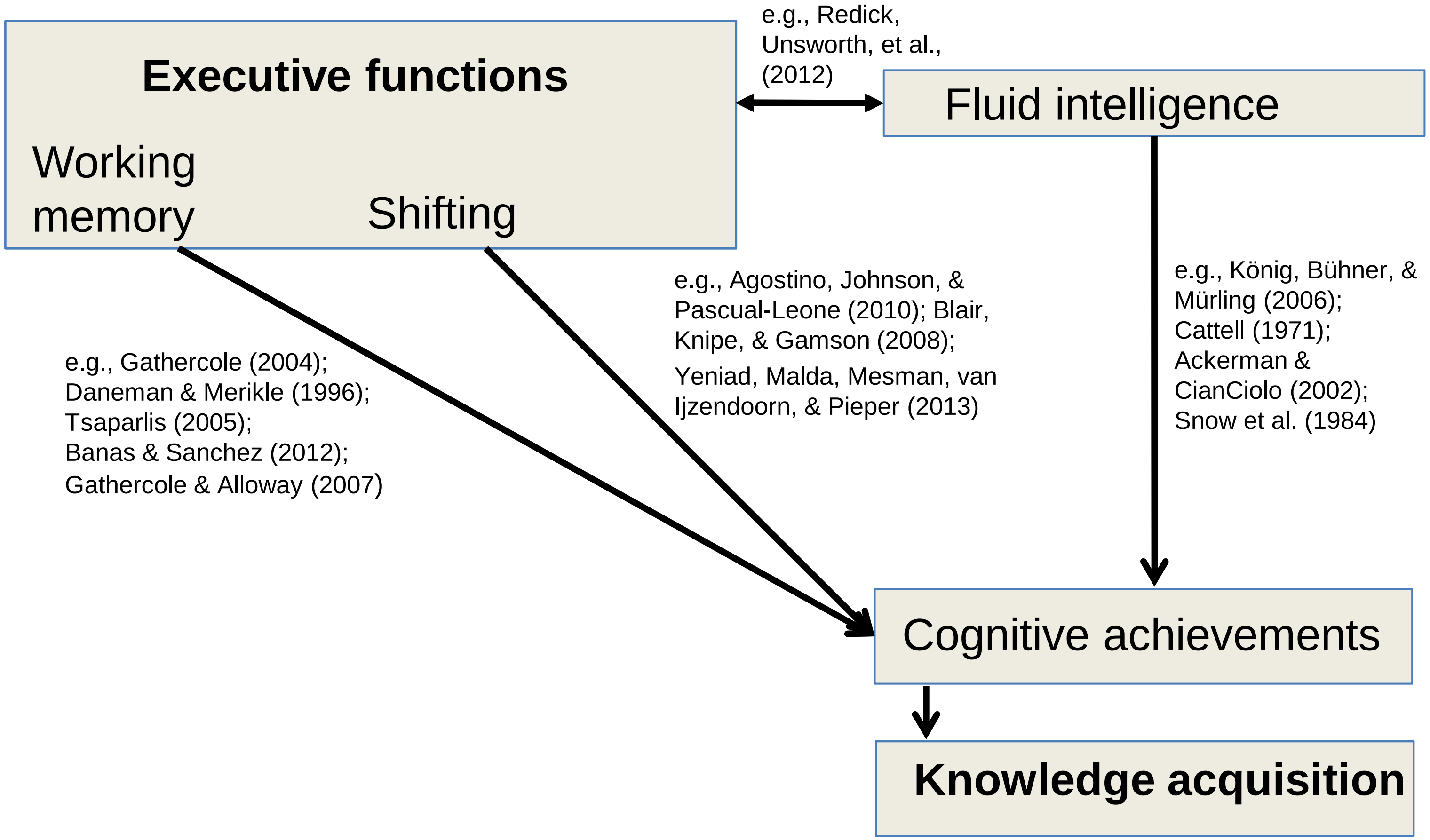
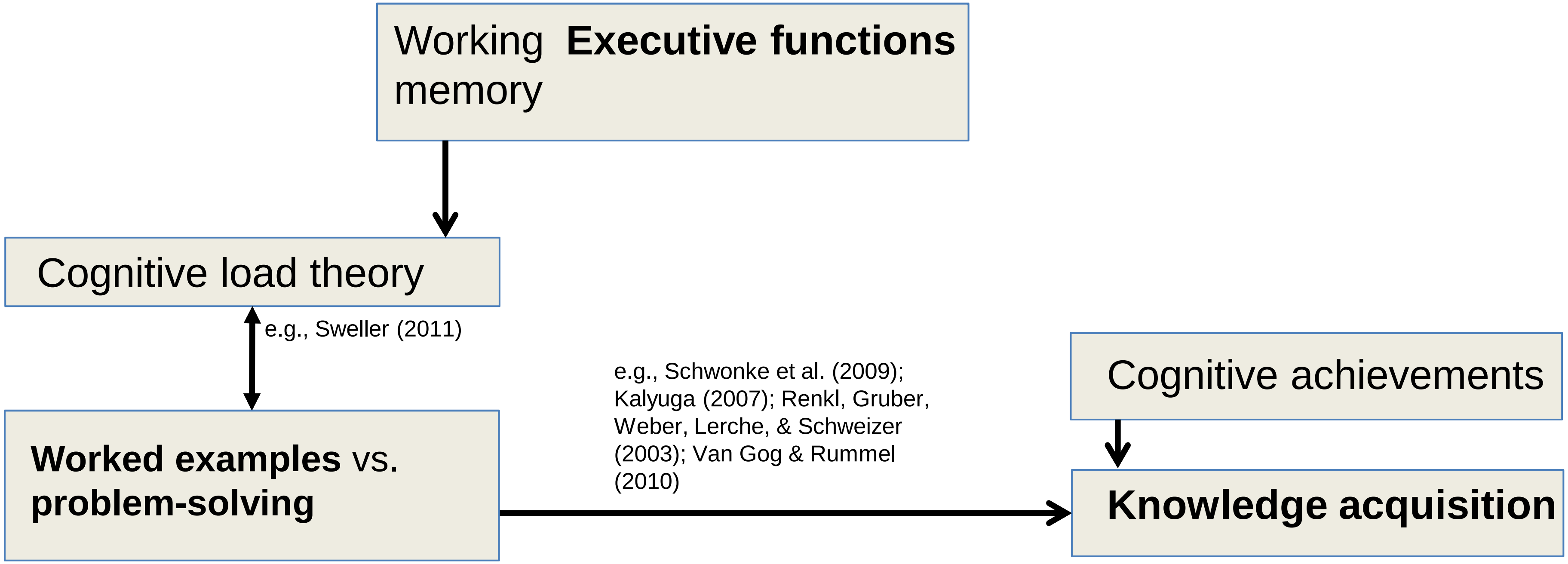
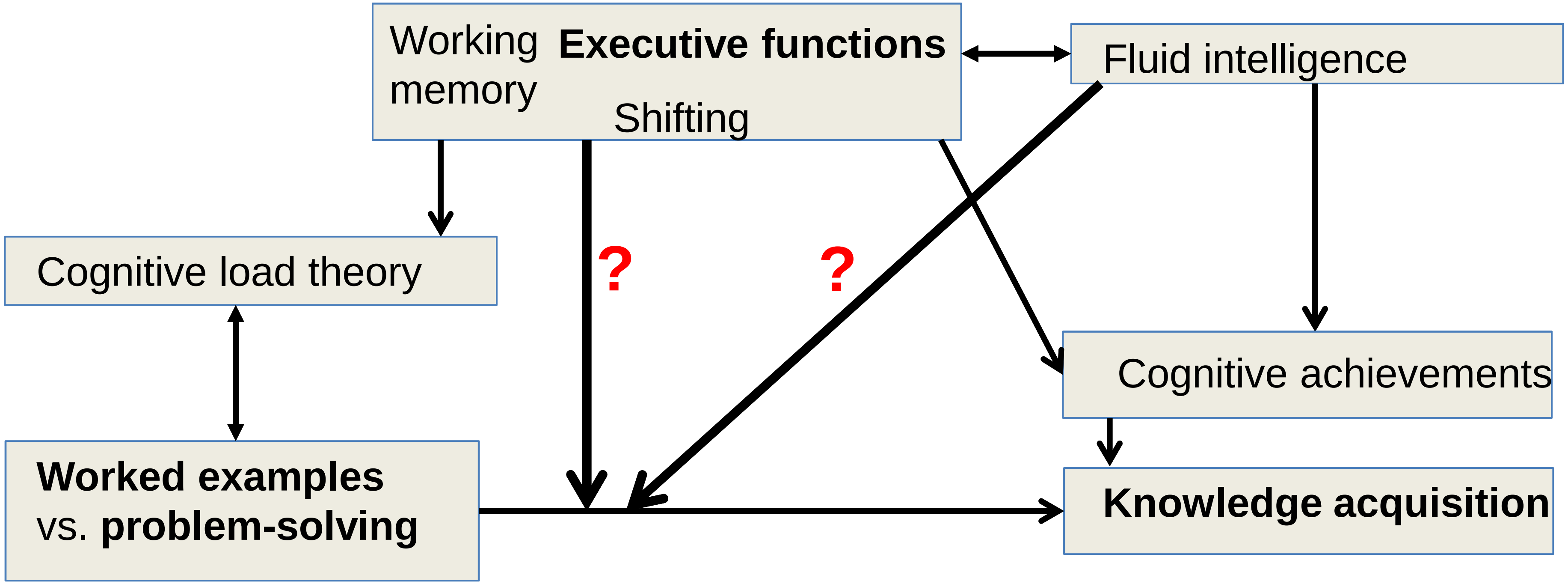
Theoretical background



Theoretical background



Overview



RQ: To what extent do the executive functions of shifting and working memory capacity as well as fluid intelligence moderate the effect of the presence of worked examples on knowledge acquisition?

Hypotheses

The benefits of worked examples will be greater for students with low working memory capacity than for students with high working memory capacity

The benefits of worked examples will be greater for students with low shifting ability than for students with high shifting ability.

The benefits of worked examples will be greater for students with low fluid intelligence than for students with high fluid intelligence.

Method

Sample and design

- *N* = 76 students (pedagogy, psychology, school psychology), mean age of 23.83 years; 67 female students, 9 male students

- Two experimental conditions (learning environments): no worked examples (problem-solving) vs. worked examples

Presence of worked examples	
no (problem-solving)	yes (worked examples)
n = 38	*n* = 38

Method

Learning environment and procedure

Computer-based learning environment: 3 statistical problems and information were presented via PowerPoint slides (no strict time limit, i.e., self-paced reading)

Pretest (prior knowledge tests, executive functions and fluid intellligence)

→ *

Intervention phase (interest and motivation prior to learning with statistical problems; Cognitive load after each statistical problem)

→

Posttest (knowledge tests)

* Participants were randomly assigned to one of the two experimental conditions

Example: Statistical Problem 1

Problem 1

Max, a cognition scientist, wants to find out whether the presence of a person has an influence on the effectiveness of cognitive training. He has acquired students of pedagogy and psychology (N = 120), whom he randomly assigned to two groups. One group completed cognitive training for four weeks alone in a laboratory; the other group completed the same cognitive training also for four weeks, but under the supervision of an experimenter. Max measured training performance (interval-scaled trait) at the beginning, after two weeks, and at the end of the training. Because Max has not yet run a study with cognitive training with a student sample, he is interested in whether the training performance of the participants differs among the three measurement times. In addition, he assumes that the effect of the presence of an experimenter is not identifiable immediately, but depends on the duration of the training. In order to guarantee a correct statistical analysis, Max also wants to consider the assumptions for his analysis. *How can the question of Max be answered statistically? Please justify your answers as much as possible.*

Responses were given on an answer sheet; Self-explanations were required in both conditions

Example: Part of the information for problem 1 (identical for both experimental conditions)

Information for problem 1

There are various statistical methods to compare two means from more than two samples. The number of samples to be compared is important as well as whether the samples are independent from each other. A one-factorial analysis of variance without repeated measurements is appropriate to compare several independent samples that are realizations of one factor or one independent variable. In this context, there is a one-factorial design because means of the stages of only one factor or independent variable are considered. If a sample is investigated on several measurement times, the values of the dependent variables on the different measurement times depend on each other. In this case, there is also a one-factorial design with one factor for the repeated measurement (independent variable). In contrast, if means from combinations of factor stages are compared, there is a multifactorial design. For example, if there are three independent variables or factors with three stages each, there is a 3×3×3-factorial design. Thus, a three-factorial analysis of variance would be used for the analysis. A special case is the combination of one factor for repeated measurement and one or several other factors. The analysis can be done with multifactorial analysis of variance with repeated measurement. If one of the factors in the example with three factors is a factor for repeated measurement (with three stages), differences between the means of the combinations of the factors can be found with a three-factorial analysis of variance with repeated measurement.

Example: First of three solution steps for problem 1 (condition with worked examples)

Solution problem 1

1. Step: Determination of the design and the independent variables as well as the dependent variable

It is a two-factorial (2x3 or 3x2-factorial) design with the independent variables (IVs) or factors “Presence of a person during the training” (two-stage, yes vs. no) and time of measurement (three-stage). The dependent variable (DV) is the training performance.

Dependent variables

- **Working memory capacity:** Mean of the three automated complex span tasks operation span (aospan), symmetry span (asymspan), and reading span (arspan) (Redick, Broadway, et al., 2012); α = .87 (aospan), α = .71 (asymspan) und α = .89 (rspan)
- **Shifting:** Mean of the tasks color shape, number letter und category switch (e.g., Friedman et al., 2008) ; r_{tt} = .91 (color-shape task), r_{tt} = .90 (number-letter task), r_{tt} = .86 (category-switch task)
- **Fluid intelligence:** Three subtests of the intelligence structure battery (INSBAT; Arendasy et al., 2004); α =.70

- **Cognitive load:** Nine steps rating scale (Paas, 1992); mean of three values; α = .80 (for three values)

➔ **Knowledge acquisition:** Difference between knowledge tests (post – pre) which measured conceptual and application-oriented knowledge

Control variables (e.g., demografic variables; interest and motivation)

Results: Preliminary analyses

- Cognitive load was correlated with fluid intelligence, prior knowledge and some oft the motivation scales

- No significant difference in cognitive load between the learning environments, $F(1, 68) = 0.93$, $p = .34$, partial $\eta^2 = .01$

Descriptive values: $M = 6.05$, $SD = 1.11$ (problem-solving); $M = 5.85$, $SD = 1.48$ (worked examples)

- Acquistion of conceptual knowledge in both learning environments, $F(1, 74) = 33.16$, $p < .001$, partial $\eta^2 = .31$
- Acquisition of conceptual knowledge did not depend on the presence of worked examples, $F(1,74) = 0.56$, $p = .46$, partial $\eta^2 = .01$

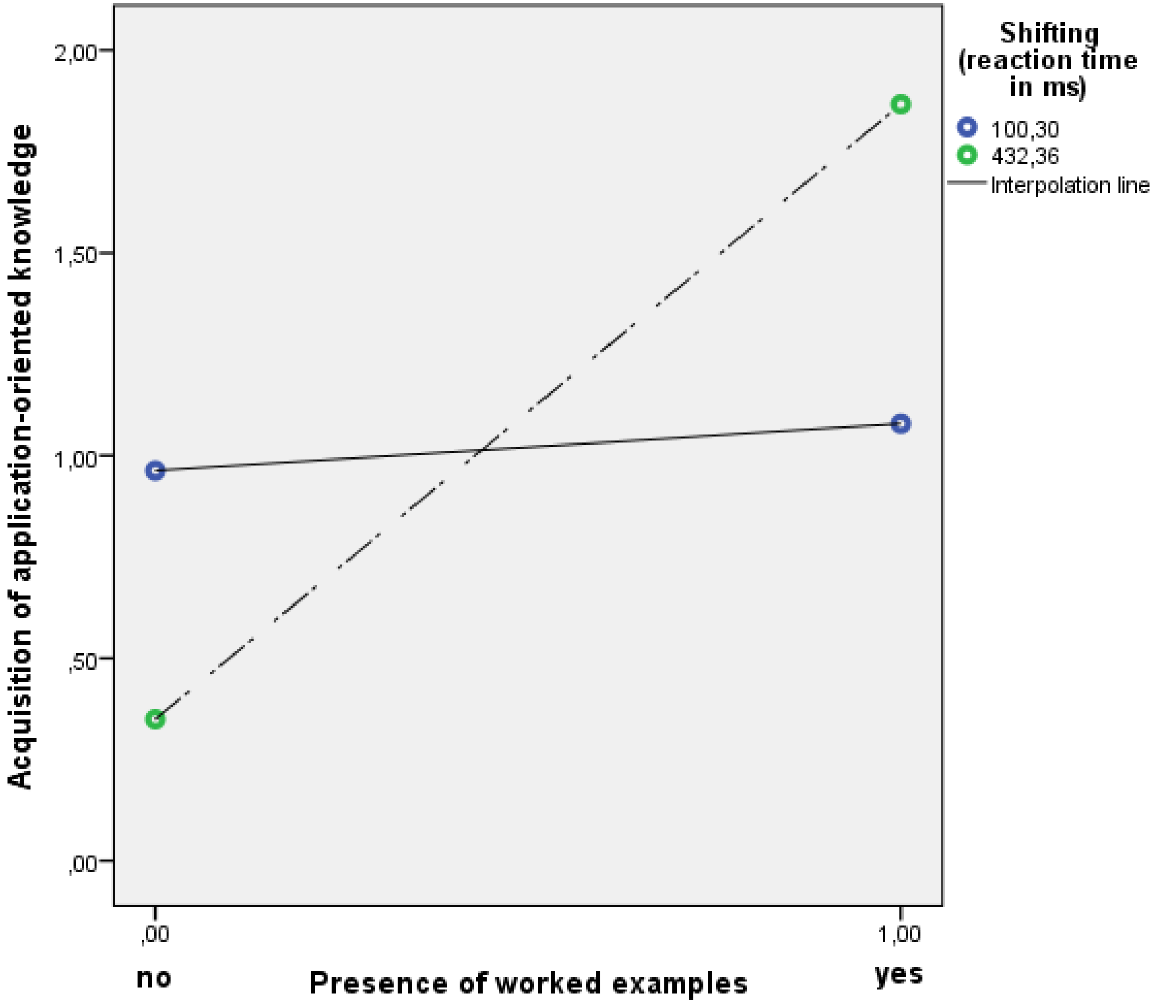
- Acquisition of application-oriented knowledge depended on the presence of worked examples, $F(1,72) = 5.75$, $p < .05$, partial $\eta^2 = .07$; Higher knowledge acquisition in the condition with worked examples

Results: Moderating role of working memory capacity

Working memory capacity (globally) had no moderating influence on the effect of the presence of worked examples on acquisition of application-oriented knowledge, b = -0.47, 95% CI [-4.07, 3.14], p = .80.

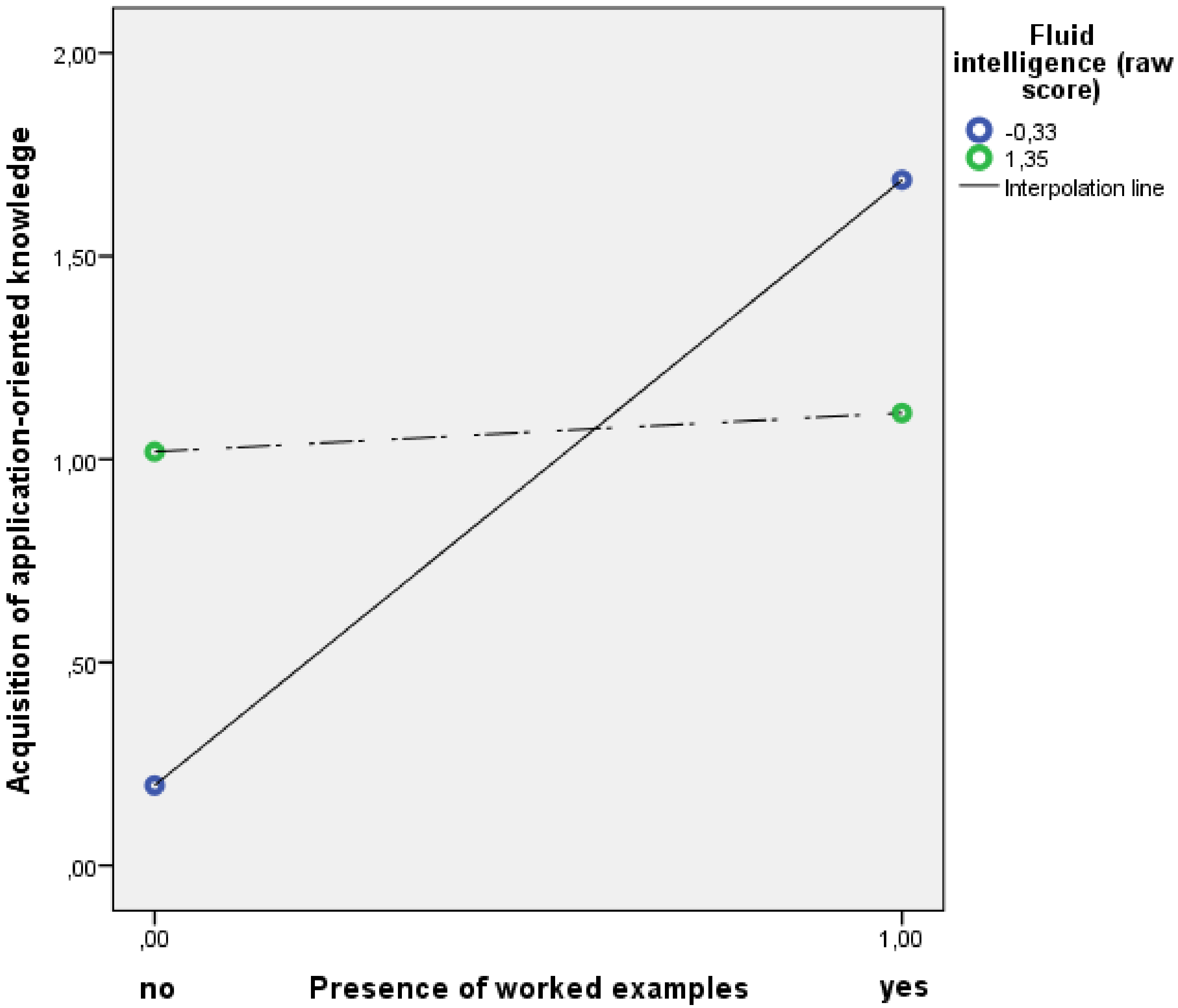
Results: Moderating role of shifting

$b = 0.004$, 95% CI [0.001, 0.007], $p < .01$



Results: Moderating role of fluid intelligence

b = -0.83, 95% CI [-1.57, -0.08], *p* < .05



Discussion

- No moderating role of **working memory capacity** ➔ no time-critical scenario; reduction of working memory load by setting more demand on the shifting ability? demands on working memory capacity could not have been significantly reduced by worked examples (see also Ayres & Sweller, 2005)

- Moderating role of **shifting** ➔ presumably, solving statistical problems requires switching between information as well as switching between information and the problem and switching between certain aspects of the problem (see also Blair et al., 2008; Van der Sluis et al., 2007)

- Moderating role of **fluid intelligence** ➔ Learners with high **fluid intelligence** seem to be better able to reason which information is relevant to solve a statistical problem more easily

Discussion

- Acquisition of application-oriented knowledge depended on the presence of worked examples
- No difference in cognitive load which was not correlated with working memory capacity but other variables ➔ doubt on the validity of the rating scale? (see also de Jong, 2010)

Limitations

- Specific setting
- Low reliabilities of the knowledge tests, but enough to show effects

Conclusions

Moderating role of executive functions and fluid intelligence could depend on learning tasks

- ➔ Moderating role of working memory capacity in a time-critical cognitive overlad scenario?
- ➔ Moderating role of shifting when frequent re-location of attention among different kinds of information is necessary?
- ➔ Moderating role of fluid intelligence when integration of different pieces of information and deciding which is/are relevant for the solution of problems is necessary?

Current study

<u>RQ</u>: *To what extent do the basic cognitive functions of shifting, working memory capacity, perceptual speed as well as fluid intelligence and complex problem solving ability moderate the effect of the presence of worked examples on knowledge acquisition under time pressure or not?*

Selected hypotheses

The benefits of worked examples will be greater for students with low shifting ability than for students with high shifting ability.

The benefits of worked examples will be greater for students with low fluid intelligence than for students with high fluid intelligence.

The benefits of worked examples will *not* be greater for students with low working memory capacity than for students with high working memory capacity in a scenario *without* <u>time pressure</u>.

The benefits of worked examples will be greater for students with low working memory capacity than for students with high working memory capacity in a scenario *with* <u>time pressure</u>.

Current study

	Time pressure (IV2)		
Presence of worked examples (IV1)		**No**	**Yes**
	No	n_{11}	n_{12}
	Yes	n_{21}	n_{22}

- **IV1**: (Improved) worked examples vs. problem solving; maximum of 6 problems
- **IV2**: Time pressure (induced via instruction and a red countdown timer lasting for 45 minutes) vs. no time pressure (stop after 45 minutes); Successful manipulation check in a pilot study with *N* = 26

Current study

Main variables

- Working memory capacity
- Shifting
- Perceptual speed (three tasks from Ekstrom, French, Harman, & Derman, 1976; Salthouse & Babcock, 1991)
- Fluid intelligence
- Crystallized intelligence (three tasks from INSBAT, Arendasy et al., 2012)
- Complex problem solving ability (COMPRO; Greiff & Wüstenberg, 2012)
- Acquisition of application-oriented knowledge (23 items)
- Cognitive load

Thank you for your attention!

Schwaighofer, M., Bühner, M., & Fischer, F. (2016). Executive functions as moderators of the worked example effect: When shifting is more important than working memory capacity. *Journal of Educational Psychology.*