Working Memory Load

during

Number Sentence Writing

with

Pictorial Math Problems

in Typically and Poor Performing Children

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Previous research

Combining pictorial information (illustrations) with written problems in math education for children in grade 5 did not make the problem easier and could even have an adverse effect (Berends & van Lieshout, 2009; Van Lieshout & Berends, 2009). This was explained within the framework of the cognitive load theory (Sweller, 1988).

In contrast, the combination of written text with problems in which they had to fill in a number sentence produced better results in grade 1 children (Van Lieshout & Berends, 2009).

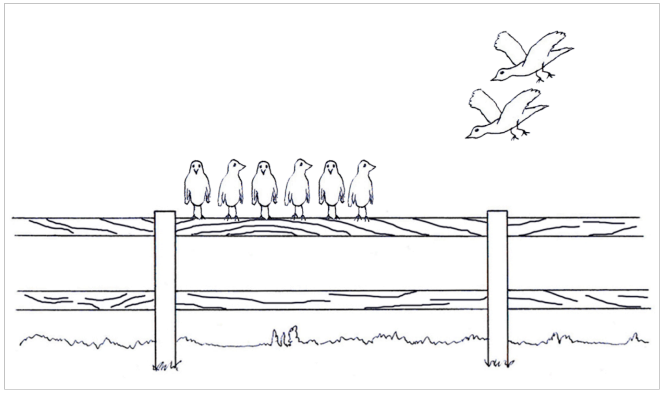
However, to help these beginning readers the text was read to the children by the experimenters. Some children did not pay attention to the written text. Therefore the unexpected result was explained as a combined modality and multimedia effect. A modality effect means that a combination of spoken text and pictures produces better performance than a combination of written text and pictures (Moreno and Mayer, 1999). A multimedia effect means that the combination of text and pictures is better than pictures alone (Mayer, 2003).

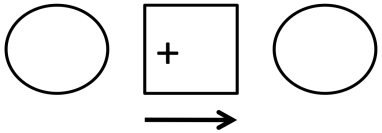
The first of the two present studies was devised to test the multimedia explanation. Experiment 2 was set up to find out why pictures that depict a decrease are more difficult than an increase.

Practicing number sentence writing

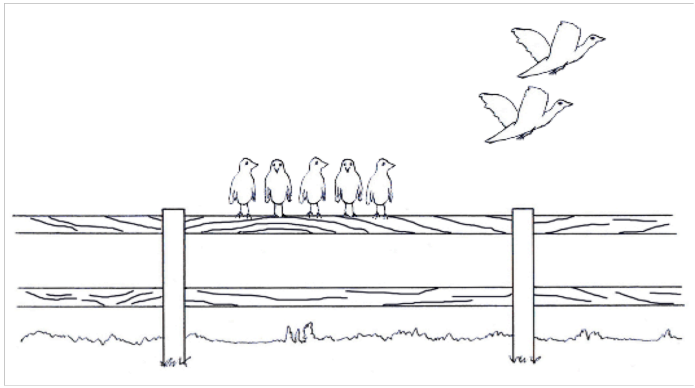
Problems that are often used in Dutch math curricula:

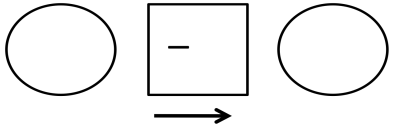
Increase problem





Decrease problem





Task: Fill in the number sentence.

(Experimental problems, not exactly the same as in math curricula.)

Experiment 1

Do decrease problems, used for practising number sentence writing, cause extra working memory load compared to increase problems? If so, a stronger multimedia effect for the decrease than for the increase problems could reveal this.

Do poor performing children experience more problems during the number sentence task due to their limited working memory resources? If so, a stronger multimedia effect for them than for the other children could reveal this.

Method

Participants

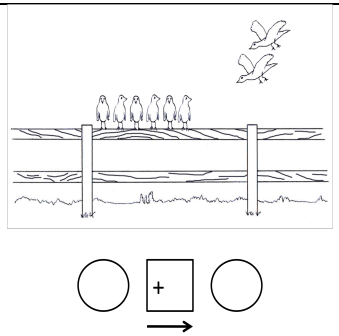
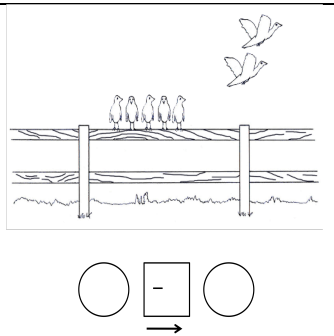
60 grade 1 students (mean age: 6.7). Four groups (*n* = 15) performing on different levels of a general math test (Cito). Nearly equal number of boys and girls.

Procedure

In each of 3 sessions 12 problems (see next page) with 3 *types of presentation formats* (only a picture, only text read to the child or the combination of both) and with two *change situations* (increase vs. decrease) in a counterbalanced design.

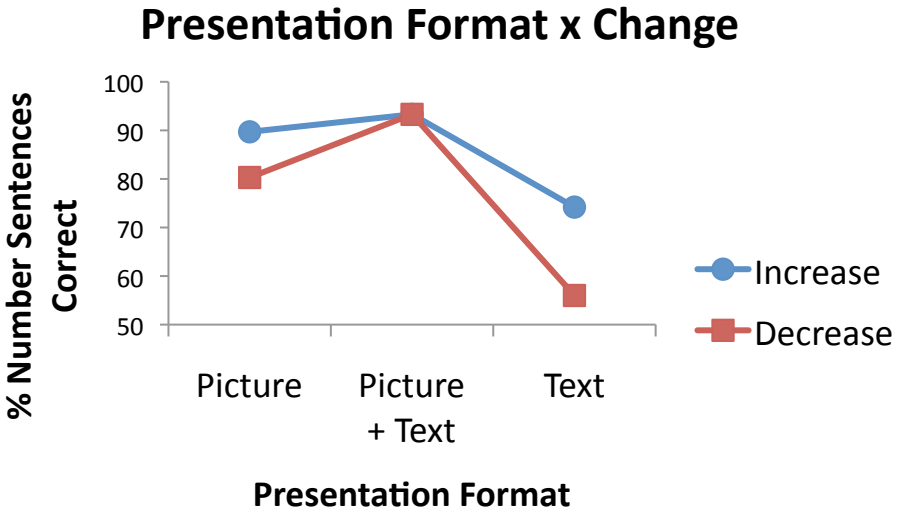
Working memory tests: *Corsi Blocks* (Visual Spatial Sketchpad) and *Backward Digit Span* (Phonological Loop and Central Executive).

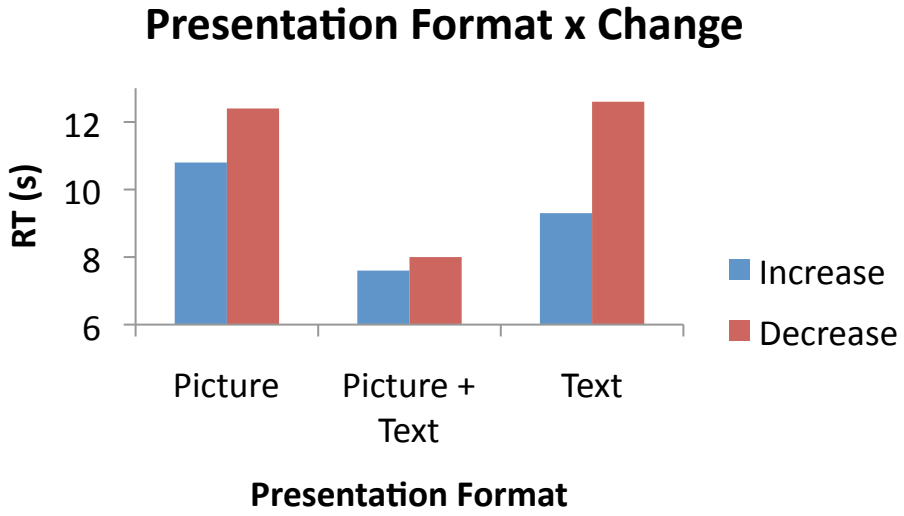
Experimental problems

Picture only		
Spoken text only	There are 5 birds on the fence. Two birds are coming. How many birds are on the fence altogether?	Two birds are flying away. There are still 5 birds on the fence. How many birds were on the fence at first?
Picture + spoken text	Combination of above	Combination of above

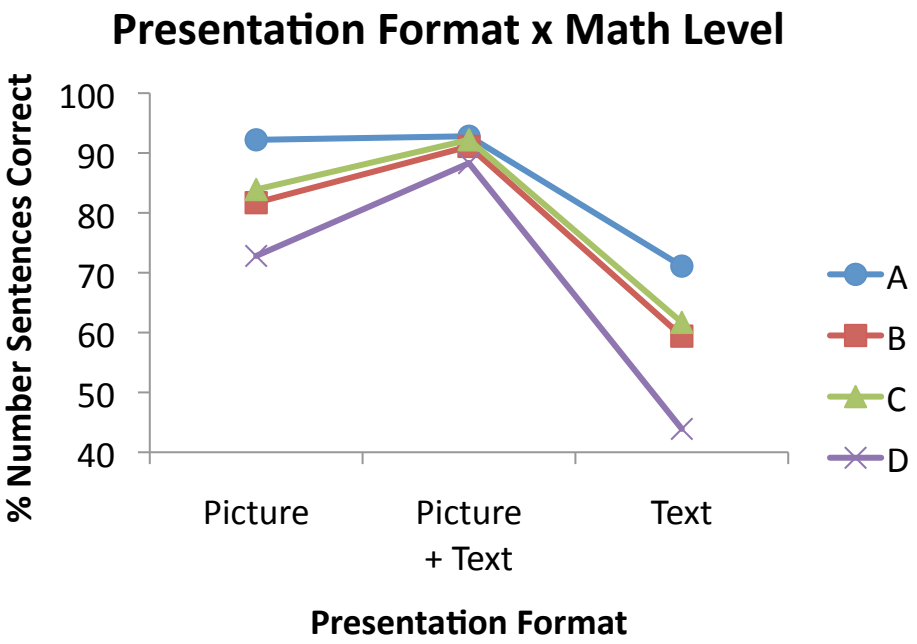
Results

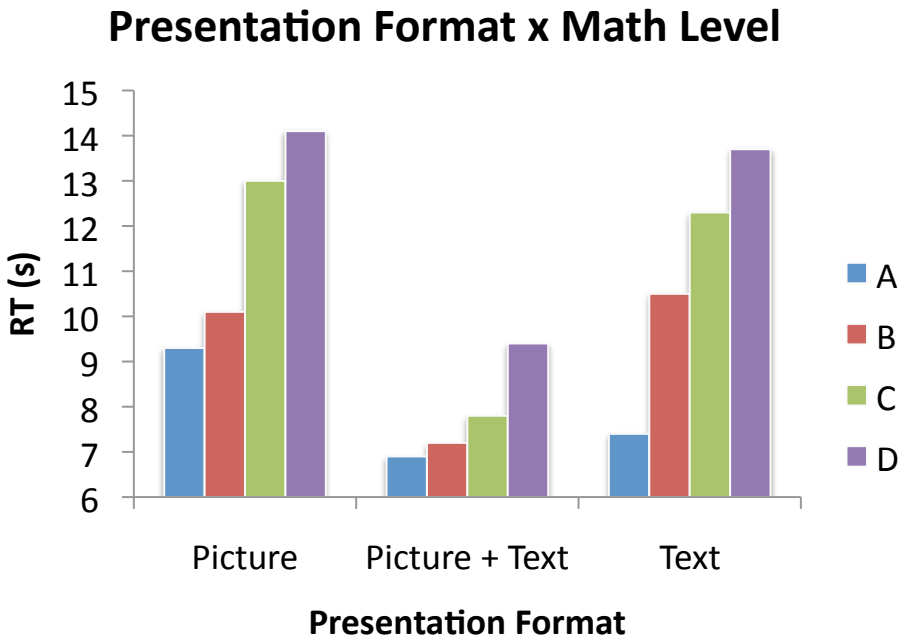
Several 3 (Presentation Format) x 2 (Change) x 4 (Math Performance Level) ANOVAs of accuracy and RT.





Significant Presentation Format x Change interaction. Significant differences only in the two 'pure' conditions. Confirmation of multimedia effect for decrease problems.





Significant Presentation Format x Math Performance Level. Pair wise comparisons: the poor performing group differed significantly from the other groups only in the two ‘pure’ conditions. Confirmation of Multimedia effect for the children with the poorest performance.

Regression analyses (simultaneous method) with VSSP and PL/CE as predictors:

- Percentage number sentences correct
  - PL/CE significant predictor in spoken text condition
- RT
  - VSSP significant predictor in picture condition
  - PL/CE significant predictor in auditory text condition and the combined picture + spoken text condition

Discussion

The shown multimedia effect indicates that pictorial decrease problems load WM heavier than increase problems. Possibly this is the result of a transformation of the decrease situation (with the unknown in the start position of the number sentence) into an addition problem.

The shown multimedia effect in poor performers confirms the hypothesis that these children have difficulties with pictorial problems as a result of their more limited WM capacity (especially the VSSP) as compared to higher performing children.

Experiment 2

In contrast with experiment 1 the effect of the place of the unknown (start or end position) and the nature of the suggested change in the situation (increase or decrease) could be evaluated separately.

If pictorial problems with the position of the unknown at the start are more difficult because of a WM taxing transformation, a multimedia presentation (picture together with auditory text) could reveal this.

Method

Participants

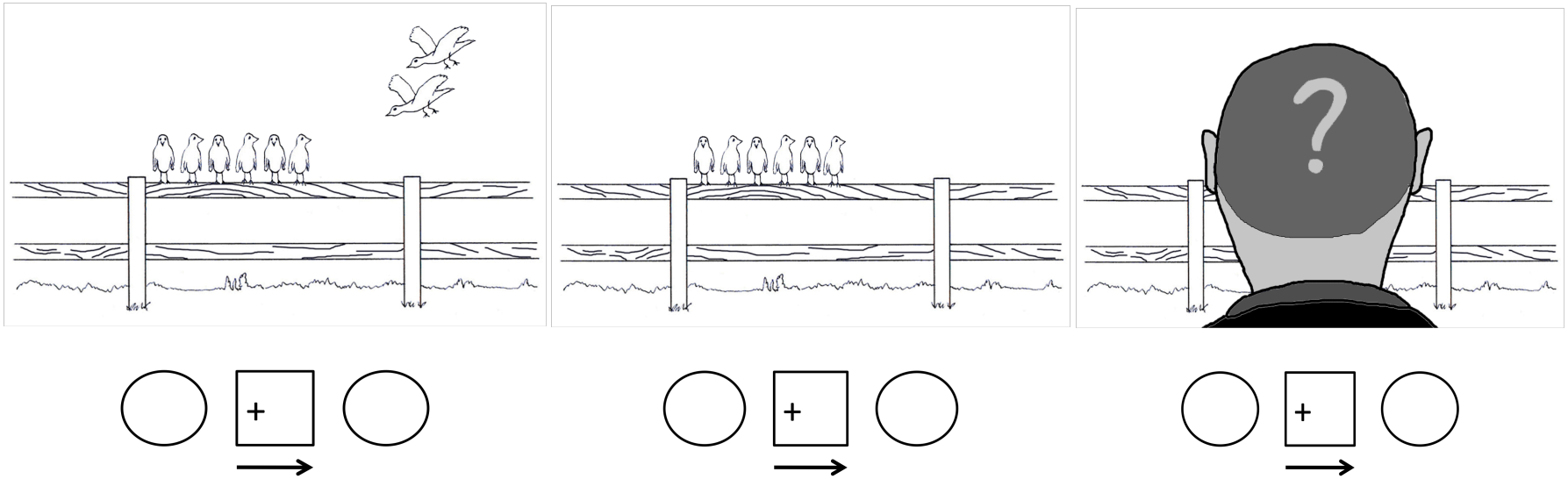
80 grade 1 students (mean age: 6.7) divided into three performing on different levels of math according to the teachers. Nearly equal number of boys and girls.

Procedure

In each of 4 sessions 12 problems (see next page) with 2 types of presentation formats (only a picture or a combination of picture and spoken text), two change situations (increase vs. decrease) and two positions of the unknown (start or end position) in a counterbalanced design.

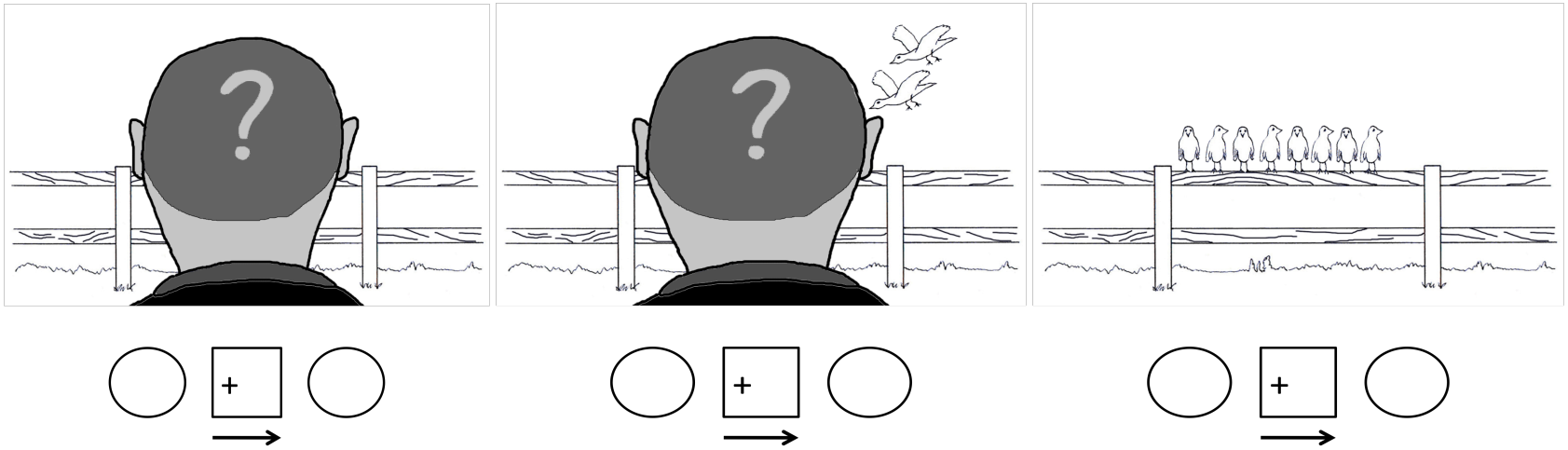
Self-paced one by one presentation of 3 consecutive pictures on a computer screen.

Example of increase situation with unknown at the end:



Decrease situation likewise.

Example of increase situation with unknown at the start:

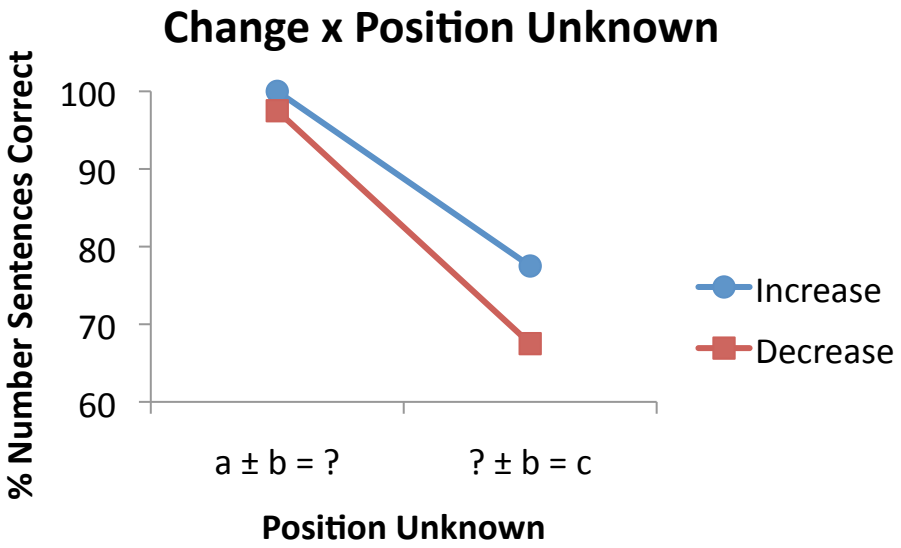


Decrease situation likewise.

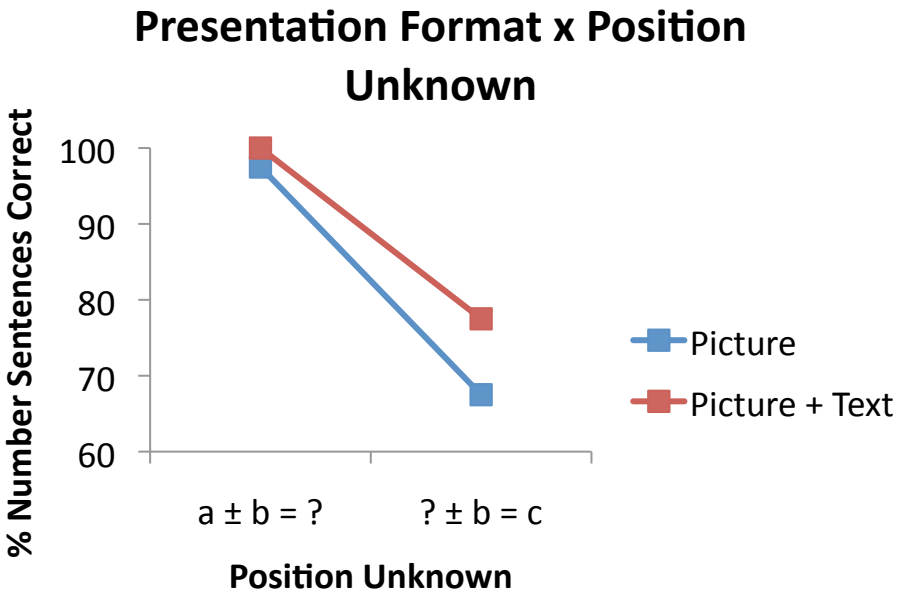
Results

Several 2 (Presentation Format) x 2 (Change) x 2 (Place Unknown) x 3 (Math Performance Level) ANOVAs of accuracy.

No interaction between suggested change (increase or decrease) and presentation format (picture only or combined with spoken text). Because of the not present multimedia effect the suggested change does not seem to be the cause of the difficulties.



Significant Change x Position Unknown interaction: Increase situation is only easier than decrease situation with the unknown in the start position (? + a = b vs. ? - a = b). However, start position unknown is always more difficult than end position unknown. Position unknown seems more important than suggested change.



Significant Presentation Format x Position Unknown interaction:
Significant difference within the problems with the unknown first.
Multimedia effect in the most difficult problem.

General Discussion

The appearance of a multimedia effect in problems with the unknown in the first position and not in problems with the unknown in the last positions supports the idea of a heavy WM load due to the possible transformation of the former problems. This transformation consists probably of changing the suggested change in a straightforward calculation (e.g. from ? – 2 = 5 to 5 + 2 = ?). Not the suggested change itself but the position of the unknown seems important.

Developers of math curriculums should take care in devising pictorial decrease problems to practise number sentence writing especially in poor performing children.

References

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