Workshop METACOGNITION & EDUCATION
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How to raise metacomprehension accuracy at school?

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Outline

1. Introduction: why is it difficult to detect misunderstanding?
2. Kintsch' model
3. How to address dynamic issues such as conceptual acquisition and conceptual change? The case of word problems in arithmetic
4. How to help students acquire concept-based inferential patterns?

Introduction

Why is it difficult to detect one's misunderstandings?

Metacomprehension often miscalibrated

- School children and adults have repeatedly been found unable to evaluate their own reading or oral comprehension

- This compromises learning efficiency.

Thiede, Griffin, Wiley & Anderson,. (2010). Griffin, Wiley & Salas (2013), Thiede, K. W., Wiley, J., & Griffin, T. D. (2011).

Theoretical assumptions

Assessing comprehension in learning is made difficult by

- **Goal ambiguity**
- **Non-diagnostic forms of self-consistency used to assess understanding**
- **The illusion of explanatory depth** (Rozenblit & Keil, 2002)

1. Goal ambiguity

Students' metacognition is sensitive to various cognitive goals

- **The test-expectancy experiment** (Thiede, Wiley, Griffin, 2011): Students can control and monitor their type of learning as a function of a goal of remembering vs comprehending
- "Poor metacomprehension accuracy may be in part due to **a lack of understanding of what comprehension means**" (ibid. p.265)
- Note that the term of "learning" in the educational literature is itself ambiguous as to the goal pursued, between
  - **a memorizing/retrieving dimension (e.g.: JoLs)**
  - **an inferential dimension (explaining) (JoCs?)**

(see also Ackerman & Beller, 2017)

2. Non-diagnostic cues

Metacomprehension, as any other metacognitive feeling, only works **when it is based on diagnostic cues.**

Among the **non-diagnostic cues** frequently used:

- Textual coherence (ease of processing)
- Shorter processing time
- Familiarity with the subject
- Easy access to some visualized components

Diagnostic cues for metacomprehension, as a matter of principle, must target subjective cues tracking concept-based, explanatory reliability.

3. The illusion of explanatory depth
(Rozenblit & Keil, 2002)

Most people feel they understand the world with far greater detail, coherence, and depth than they really do. Why?

- Two confusions:

1. between what is represented mentally with what can be recovered from perception.
2. between **higher and lower levels of explanation.**
   - Artefacts and natural phenomena have hierarchical explanations : functional versus causal mechanisms, which themselves are hierarchically explained
   - Granting the complexity and indeterminate character of the lowest explanatory level, self-testing one’s knowledge of explanations is difficult

Kintsch 1994 model: used by most metacomprehension theorists

Superficial versus deep understanding
McNamara, Kintsch, Songer & Kintsch, 1996, Recanati, 2001

- In **superficial processing**, text-base propositional content is associated with a concept minimally characterized i.e. a so-called "deferential concept" and/or a minimally characterized referential domain.
  - A deferential file is created to be filled-in at a later date. (Recanati, 2001)

- In **deep processing**, a situation is simulated, incl.
  - identifying the concepts and referents involved
  - representing the factual *and* causal structure of the events described
  - Hence, making inferences and elaboration possible.

The diagnostic (predictive) cues for metacomprehension

- Often explained in terms of Kintsch's situation model (Thiede et al. 2010, Jaeger & Wiley, 2014)
- **Surface features:** memory of exact words
- **Text-base features:** meaning generated by syntactic structure, propositions, and relations between propositions and between referential and conceptual meaning (objects and properties)
- **Situation-level:** incorporates general knowledge from memory about similar situations. Supposed to be the target level for comprehension

How to account for the fact that students have a level-specialized sensitivity to coherence?

Two complementary accounts

- **A trade-off account of control**

  Understanding reflects the way students' goals are selected. (see text expectancy: Thiede, Wiley & Griffin, 2011).

  Selecting a metacognitive goal is constrained by specific trade-offs that are context dependent

  Students who struggle to make sense of a sentence meaning may assess understanding at a text level, or even at the surface level.

Main control trade-offs

- information **exploration-exploitation** trade-off between seeking new information and exploiting familiar resources (Boldt et al., 2019).
- **Informativeness-learnability** trade-off in curiosity (Goupil & Proust, 2023)
- **Accuracy-informativeness** trade-off (Yaniv & Foster, 1995)
- **Speed-accuracy** trade-off (Fiedler, McCaughey, Prager, Eichberger, & Schnell, K. (2021).
- **Trade-off between shallow versus deep executive focus** on a task (Musslick & Cohen, 2021)

Executive trade-off in task representation

Musslick &Cohen (2021):

There are 2 different kinds of task representation in working memory

If the representation of the task corresponds to a deep attractor, then even with small perturbations (e.g., due to noise) the system is most likely to settle back to the same state (akin to a ball bouncing around in a deep well).

→the system is robust to noise.

Conversely, shallow attractors make the system more susceptible to noise (i.e., make it easier for the ball to pop out of the well), but also make it easier to switch from one state to another

→ flexible task switching comes at the expense of robustness to distractors

A case study: Metacomprehension in math students

An ease-of-processing/inferential power trade-off

Understanding arithmetic in primary school

Fischbein (1989) proposed that **a tacit model impacts arithmetical reasoning**: (multiplication as a repeated addition and division as a partitive situation).

Following the same idea, Gvodic & Sander (2020) identified **tacit models for addition**: as acquiring items, and subtraction: as loosing items.

The problem however, is that intuition blocks conceptual reasoning. When a problem fits the implicit model, it directly activates procedural skills without relying on conceptual reasoning

The relations between teaching preferences and students' metacomprehension

Math teachers tend to favor intuitive simulations, when asking students to solve "word problems" because they provide students with a **sense of coherence** **between familiar situations and arithmetic problem solving.**

However, an intuitive simulation fails **to control students' attention** to arithmetic content that would allow students to flexibly solve problems.

Furthermore, it leads students to **experience an illusory** metacomprehension.

Sander proposes an explicit scaffold for arithmetic problem-solving for students

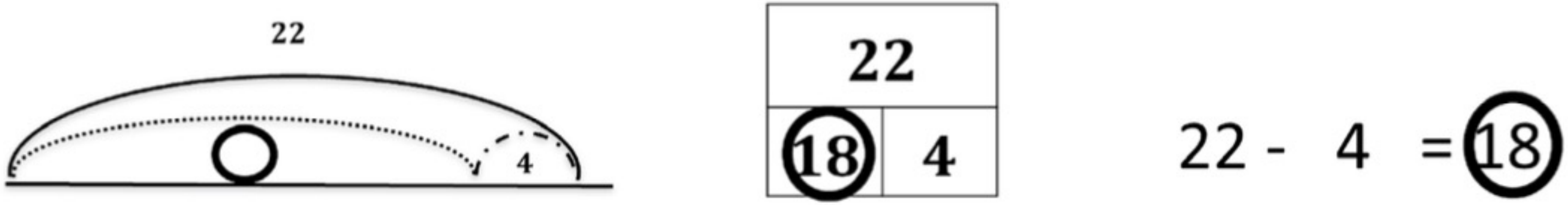
1. Describing a word problem in arithmetic in terms of a specifically arithmetic schematic representation
2. Identifying what is known and what is searched in the problem
3. Placing these values on the schemas
4. Computing the arithmetic value of the operation.
5. Inscribing it on the schema
6. Reporting in words the result of the problem.

Gvozdic Sander 2018 lost cost vs high cost strategies

a Low cost mental simulation problem

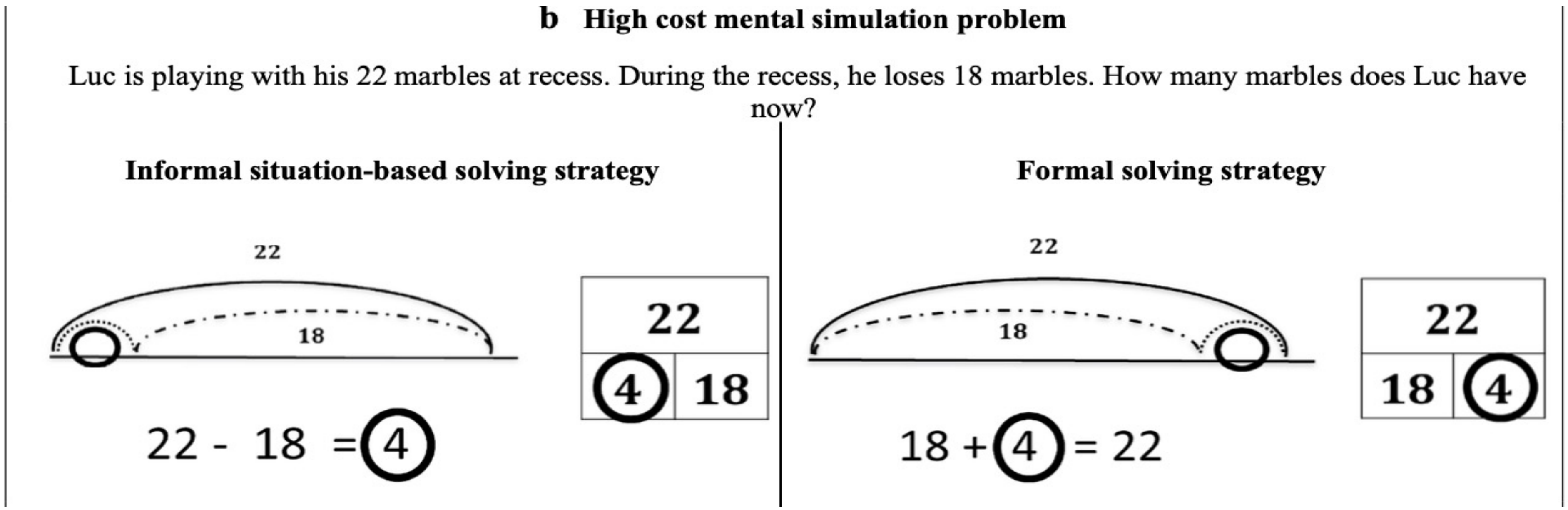
Luc is playing with his 22 marbles at recess. During the recess, he loses 4 marbles. How many marbles does Luc have now?

Informal situation-based solving strategy



The informal situation-based strategy is to simulate the action described in the text: losing 4 marbles. It, therefore, consists of mentally counting down 4 from 22. This is then noted as the subtraction 22 – 4. In the case of this low cost mental simulation problem, this mental simulation is easy to perform.

High cost simulation problem



*The informal situation-based strategy is to simulate the action described in the problem: losing 18 marbles. It, therefore, consists of mentally counting down 18 from 22. This is noted as **direct subtraction 22 – 18.***

*The formal arithmetic strategy relies on disengaging from the semantic context and changing how the situation is addressed, leading students to solve the problem by searching for the distance between 18 and 22. This entails recoding a direct subtraction situation into **an indirect addition,** which is then noted as 18 + 4 = 22*

Conceptual knowledge vs procedural know-how

Conceptual knowledge involves

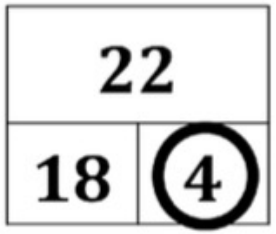
- understanding why certain procedures work for certain problems or
- indentifying the purpose of each step in a procedure” (Crooks and Alibali, 2014)

Procedural knowledge is the ability to realize a succession of operations leading to a final result (Rittle-Johnson & Siegler,1998)— a “know how” (Baroody, 2003).

Semantic recoding needed

The **formal arithmetic strategy requires both teachers' and students' disengaging from a familiar** semantic context being simulated

This entails **recoding a direct subtraction situation into an indirect addition**, which is then noted as 18 + 4 = 22.



Students' self-explanation: a persistent preference for informal situation simulation

- Some student dyads asked to **self-explain** how to **formally represent** a given word problem tend to persist giving intuitive, but wrong representations of the problem and its solution.
- Self-explanation is always under threat of **a higher self-consistency** for intuitive solutions. Hence it is recommended to only use in consolidated learning episodes.
- Tools designed to help students evaluate what they know **need to be inserted in the teaching material (more to come).**

A potential mechanism for metacomprehension: self-consistency

Self-consistency as the information source of evaluating one's understanding?

Feelings of confidence **do not statistically track validity,** they **track reliability understood as self-consistency**, i.e., the amount of variability of one's own decisions over time. (Adiv & Koriat, 2015, Koriat 2012)

Self-consistency (Koriat & Adiv, 2015)

- Self-consistency is measured by the coherence among the sampled representations that are activated whenever evaluating one's memory/reasoning in a given trial.

- A high self-consistency (getting the same evaluation over time) generates a high degree of certainty with respect to an on-going cognitive task.

Highest self-consistency predicts majority response

- Because people in a culture **share** the population of representations associated with an item (shared knowledge, wisdom of the crowd phenomena), they tend to give the same response (the majority response).
- Response speed is **higher for the majority response** (less cues sampled)
- This holds for correct and consensually wrong decisions

The mind approximates Bayesian inference by sampling (Vul, Tenenbaum et al. 2009)

- "We find that under reasonable assumptions about the time costs of sampling, making many **quick but locally suboptimal decisions based on very few samples may be the globally optimal strategy over long periods**.

- These results help to reconcile a large body of work showing sampling-based or probability matching behavior with the hypothesis that human cognition can be understood in Bayesian terms.

Consequences for pedagogy

- Primary school teachers may have different ways of assessing the cost-benefit trade-off of semantic recoding
- Teacher's choice of wording determines type of understanding and of metacomprehension in their students
- Students monitor their comprehension as a function of the word problems they are presented with.

- This suggests systematic ways of deepening understanding in students across fields (based less on monitoring than on control)

Implementing comprehension-friendly teaching methods

(Meta) comprehension can be stimulated at 3 metacognition-sensitive articulations in school tasks:

Before task: concept-focused presentation of the work of the day ("interactive menu du jour");

after ZPD analysis and stimulation of curiosity

During task: enhancing comprehension every 20 mn by short concept-focused quizzes about heard or read contents

After task: encourage conceptual summaries in a learning diary written at home & discussed the next day

Enhancing the value of conceptual goals of learning in primary school

- **The menu of the day**: an active selection and presentation of conceptual goals **by learners**
- Frequent **concept-focused exercises**, helping learners to identify whether or not a lesson sequence was understood (3AltFC questions: summaries/schematic representations, etc.) (implicit goal: understanding the inferential potential of a concept)
- **Post-learning exercise**: journal of learning (preferably at home), **summarizing what the content of learning was, how well it was understood, what remained to clarify.**

Emphasizing the conceptual goal served by **every** school activity

- In particular, when using multi-modal instruments, maps, tables, drawings, diagrams, help pupils understand in detail how they help clarify contents, or why illustrations **sometimes do not help**.

- A permanent emphasis: enhance the difference between **instructions (consignes) with learning goal (concept/theory)** which vulnerable students tend to overlook.

Train the pupils to distinguish between clarification questions in the first stage and integration questions in the second stage

- **Clarification questions lead them to grasp what is being said.**
- **Integration or connection questions lead them to reason on the basis of what is said.**
- Explain why ... ?
- Explain how ... ?
- How are .... and ... similar?
- What would happen if ...?
- Find a new example of ...
- What are the strengths and weaknesses of ....?

Disputatios

- Organize disputatios where two groups of students are randomly assigned the defence of a given view or theory (after studying documents)

- Goal: develop understanding of each conflicting view, and promote deliberation.

Thanks for your attention

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