Young Children's Experimentation, Data Interpretation, and Justification Abilities

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INTRODUCTION

- **Experimentation** and **data interpretation** are core components of scientific reasoning (SR) and vital to students' understanding of science [1]
- Recent evidence indicates children hold SR abilities already in early childhood, but related research mainly relies on multiple-choice (MC) tasks [e.g., 2, 3]
- **Do MC task formats overestimate young children's understanding in SR?** Little is known about young children's explicit understanding in SR; an implicit awareness might emerge before an explicit judgment capacity [4, 5]
- Using open-ended prompts to ask children to explain their MC task judgments is an effective way of eliciting their explicit understanding in SR [6]

In the current study, …

- …we used established forced-choice SR tasks with a scarcely studied age group (early elementary school age), examining their understanding of (in)conclusive tests and their ability to evaluate various data patterns
- **…we assessed children's verbal SR task judgment justifications to gauge their explicit understanding of experimentation and data interpretation**

METHOD

Participants

N = 167 | M_{age} = 89 mos. (7;5 yrs.; SD = 1.54 mos.) | Sample from Munich, GER

Multiple-Choice (MC) Questions

Data Interpretation

- 7 items from the *Science-K* and *Science-P Reasoning Inventories* [2,7]
- **Perfect covariation, imperfect covariation, and (un)confounded data patterns**
- 1 control question and 1 MC question per item; each scored as correct (1) or incorrect (0)

Experimentation

- 9 items from the validated *Science-K* and *Science-P Reasoning Inventories* [2,7]
- **Focus on the Control of Variables Strategy (CVS) and (in)conclusive tests**
- 1 control question and 1 MC question per item; each scored as correct (1) or incorrect (0)

Justification Questions

Data Interpretation

- One justification question per data interpretation MC item (i.e., 7 questions)
- Justifications were assigned integer scores between 0 and 3

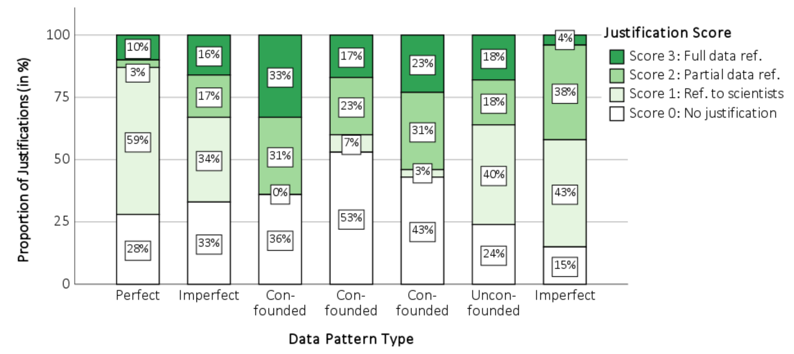
Experimentation

- Single justification question following the final experimentation MC task
- Justifications were assigned integer scores between 0 and 3

RESULTS

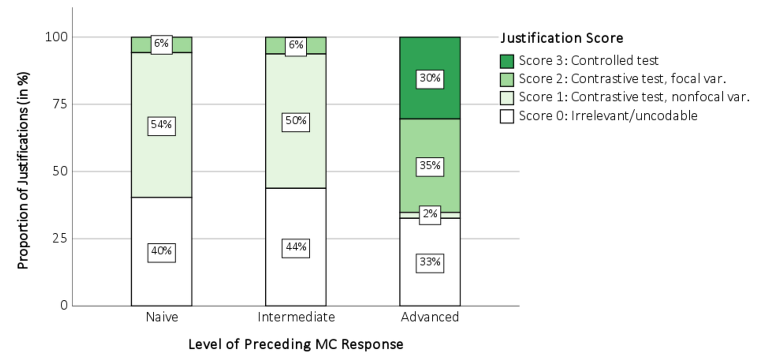
7- to 8-year-old children's justifications for their multiple-choice (MC) task judgments indicate an emerging *explicit* understanding of experimentation and data interpretation

In justifying their **data interpretation** task choices, up to 64% of children made correct and specific references to the data at hand



Note. Justifications were coded only for children who gave a correct MC response. Accordingly, n varied by item, ranging between 30–135.

In justifying their **experimentation** task choices, most children showed an understanding of variable contrasting but neglected variable control



Note. N = 162; justifications were coded regardless of MC response.

Data Interpretation, Perfect Covariation:
"Why does Robby believe this?"

"Because these are good teeth"
Score 0: Irrelevant/uncodable

"Because he saw in the picture that the children who chewed red chewing gum have bad teeth"
Score 2: Correct reference to parts of the data

"Because the scientists tested it"
Score 1: Reference to scientists

"Because he saw the results of the study, and for the green chewing gum children had good teeth, and for the red chewing gum they had bad teeth"
Score 3: Correct reference to the full data

Experimentation:
"Why is this the best idea?"

"Because double-deckers don't fly well… And there are no double-deckers here"
Score 0: Irrelevant/uncodable

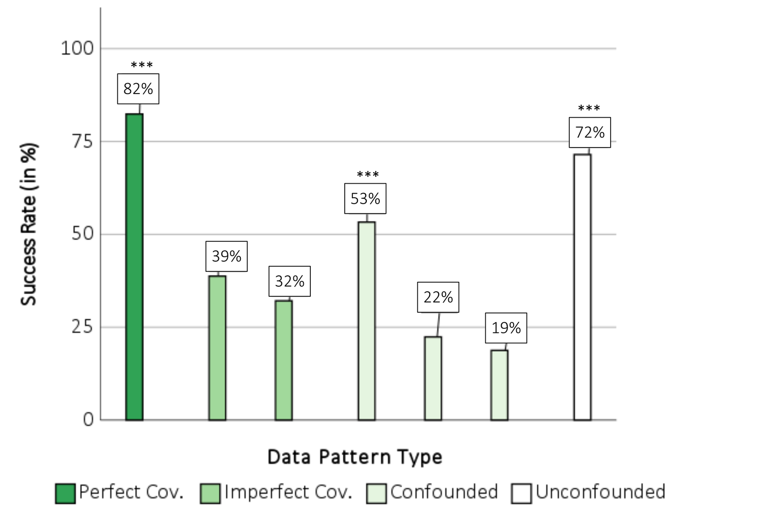
"Because here the two planes' elevators are different"
Score 2: Contrasts the focal variable but no mention that all else is the same

"Because there are two different planes so one can check which one is best"
Score 1: Mentions that the planes are different without specifying

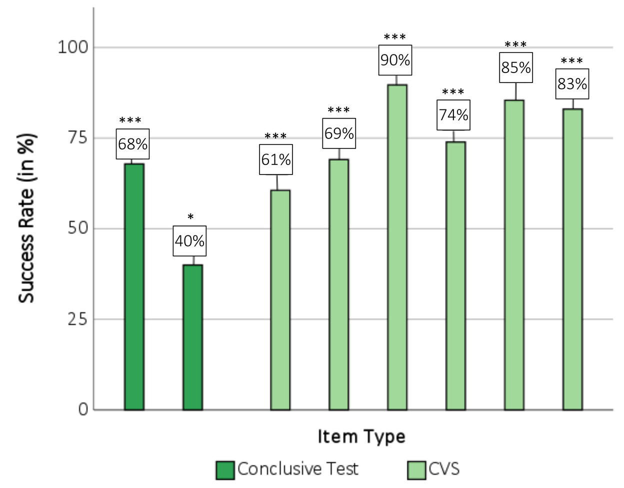
"Because everything except the two planes' elevators is the same"
Score 3: Mentions that everything except the focal variable is the same

7- to 8-year-old children show higher success rates in MC experimentation tasks than in MC data interpretation tasks; they struggle most with interpreting confounded evidence

In **data interpretation**, on average, children correctly solved 3 out of 7 MC items (p = .642); success rates varied strongly by data pattern type



In **experimentation**, on average, children correctly solved 6 out of 8 MC items (p < .001); success rates were above chance for all items



Note. N = 164 (data interpretation) and 166 (experimentation); *p < .05, **p < .01, ***p < .001. Both for data interpretation and experimentation, single-item performance was tested against chance using a one-sided binomial test. Each item had three response alternatives with one right solution (P(correct) = 33%).

TASK MATERIALS

Example Materials: Data Interpretation (Perfect Covariation)

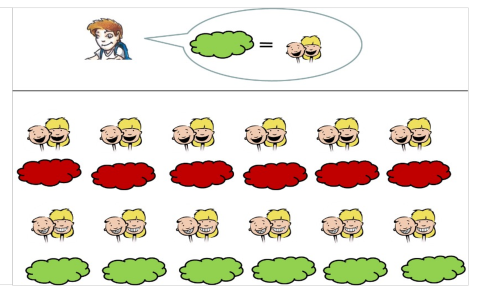
"Robby believes that green chewing gum makes bad teeth."

Control question: *"What does Robby believe?"*

"Scientists tested many children with red and green chewing gum. Here are the results of the study. Let's have a look:

These children chewed red chewing gum and have bad teeth.

These children chewed green chewing gum and have good teeth."



Multiple-Choice Question:
"Robby has seen the results of the study. What does Robby believe now?"

A) Green chewing gum makes bad teeth.
B) Red chewing gum makes bad teeth.
C) The kind of chewing gum does not matter.

Justification Question: *"Why does Robby believe this?"*

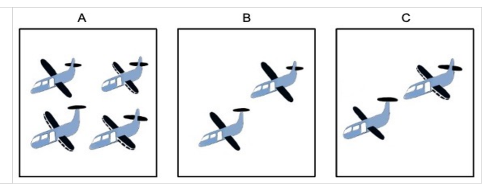
Example Materials: Experimentation

"Mr. Miller builds airplanes. He wants them to use as little fuel as possible. He has various ideas about what influences an airplane's fuel consumption."

"He thinks: A plane can have a round or sharp nose." *"He thinks: The tail wing could be attached high or low."* *"He thinks: A plane can have double or simple wings."*

"Mr. Miller thinks: It might depend on whether the tail wing is attached high or low."

Multiple-Choice Question:
"What should Mr. Miller do to find out if the position of the tail wing is important or not for fuel consumption?"



Justification Question: *"Why is this the best idea?"*

Note. Translated and adapted version of the "Airplane" item originally developed by Bullock and Ziegler [8]

DISCUSSION

- We provide new evidence that **an explicit understanding of data interpretation and experimentation may start emerging around early elementary school age**
- Children's justifications tended to align with their MC task judgments, suggesting that **children's performance in the commonly used forced-choice SR task paradigm builds not just on implicit awareness but explicit understanding**
- Children succeeded more often and provided more adequate justifications in experimentation than in data interpretation; they showed partial competence in interpreting data patterns and proposed sensible variable contrasting strategies

References

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Acknowledgments

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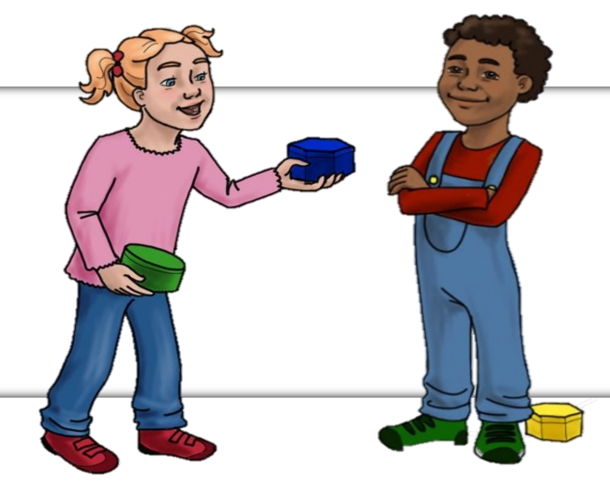

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OSF Materials available here: