Acquiring complex conditional sentences and learning to understand the basic principles of scientific enquiry

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Introduction

What determines when children start to understand the basic principles of scientific investigation?

Instruction? General reasoning ability? Both?

Could other components of cognitive development help?

Scientific investigation principles are often described using "if" sentences, which are hypothetical, sometimes also counterfactual. We explored whether the acquisition of such language is related to early vs. late understanding of scientific principles, specifically **hypothesis testing** (e.g. Sodian et al., 1991) and **control variable strategy** (e.g. Chen & Klahr, 1999).

Hypothetical, counterfactual conditional sentences:

- *If I had the money, I would buy this car.*
- *If I had had the money, I would have bought that car.*

Main Hypothesis

Children who have acquired complex conditional sentences would be more likely to show understanding of hypothesis testing principle and control variable strategy

Method

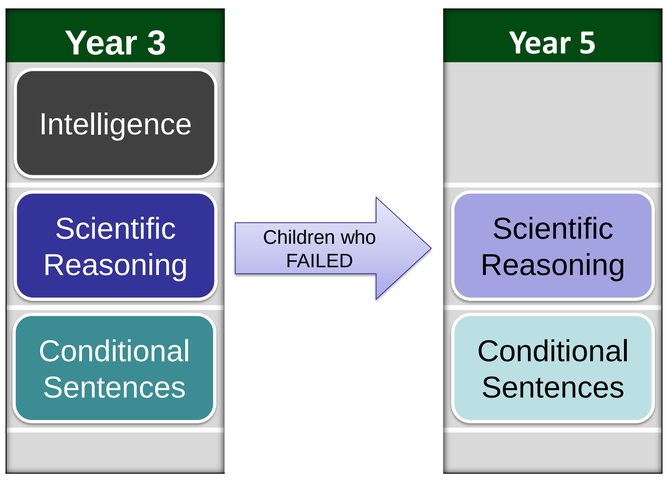
Participants

98 children (47 girls)

First tested in Year 3 (7-8-year-olds)

3 unselective primary schools (Oxfordshire) with demographically varied catchment areas

Design



Tests Administered

INTELLIGENCE

NNAT (Naglieri Nonverbal Ability Test, Naglieri, 1997)

VESPARCH (Verbal and Spatial Reasoning for Children, Mellanby et al., 2009)

CONDITIONAL SENTENCES

Conditional Sentence Repetition Test (based on Svirko, 2011)

Conditional Sentence Comprehension Test (Gabbott, 2014)

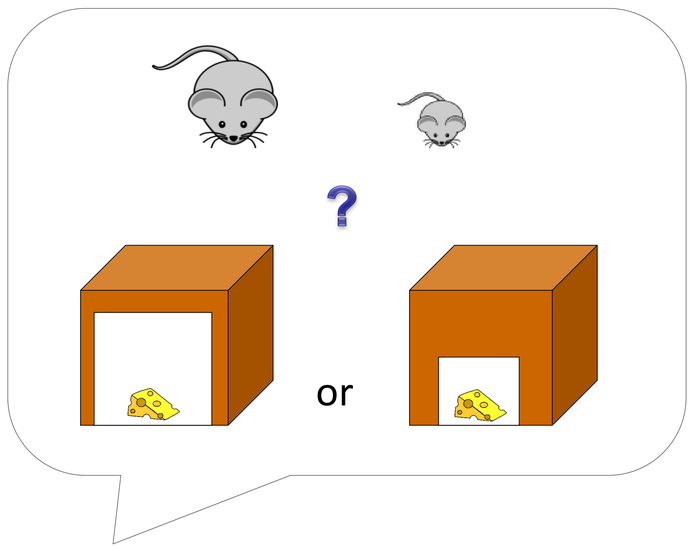
SCIENTIFIC REASONING

Mouse Test (Sodian, 1991)

Plant Test (loosely based on Chen & Klahr, 1999)

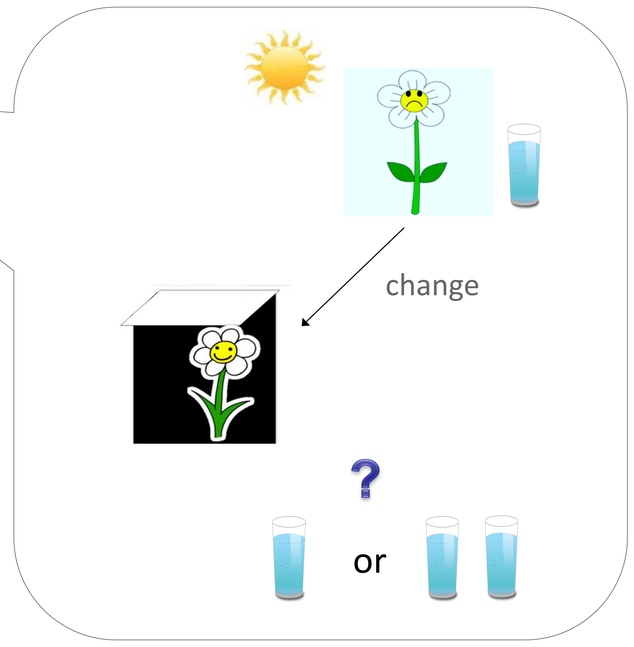
Scientific Reasoning Tests

Hypothesis Testing



Key Question:
'Which box should they put the food into if they want to find out if the mouse is a big daddy mouse or a little baby mouse? Why?'

Control Variable Strategy

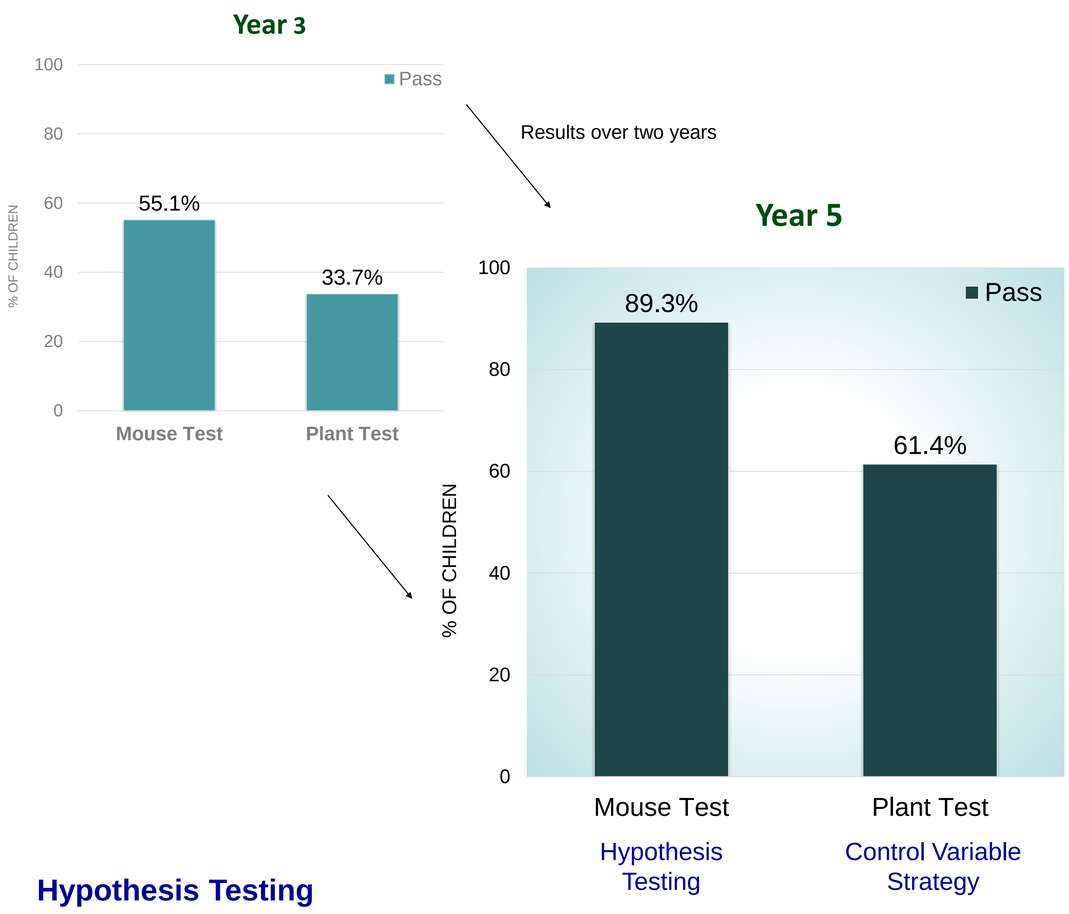


Key Questions:
If Lucy wants to be sure that it is being in the shade that makes the plant grow better, should she still give it one glass of water like before? Or should she give it two glasses of water? Why?'

Results

Conditional sentence repetition and comprehension not significantly related (p=0.1)

Performance on the science reasoning tests:



Hypothesis Testing

- NO school difference
- Good understanding of hypothetical conditional sentences in Year 3 predicted showing understanding of hypothesis testing early (Year 3) versus late (Year 5) (Model change $\chi 2$ =5.76, df=1, p=0.016), controlling for verbal and non-verbal intelligence (Model change $\chi 2$ =6.36, df=1, p=0.042).
- 10.7% (9 children) who showed no hypothesis testing understanding in Year 5:
  - Poorer on non-verbal ability: M=84.5 compared with M=96.0 for those who passed Year 5 mouse test (p=0.041).
  - Not different on verbal ability.
  - Not different on conditional sentence comprehension
  - Poorer on conditional sentence repetition: Median=5 compared with Median=7 for those who passed Year 5 mouse test (p<0.001).

Main Findings

Control Variable Strategy

- NO school difference
- We compared the children who failed the plant test at both time points to those who passed the plant test either in Year 3 or Year 5.
- Conditional sentenced comprehension in Year 3 significantly predicted passing the plant test by Year 5 (Model change $\chi 2$ =6.17, df=1, p=0.013), on top of verbal and non-verbal intelligence (Model change $\chi 2$ =12.79, df=1, p=0.002).

Conclusions

Understanding hypothetical conditional sentences predicts understanding the hypothesis testing principle and the control variable strategy independently of general reasoning ability.

Variations between unselective primary schools in the methods, timing and resources available for science teaching with the current curriculum do not appear to influence how early children form the understanding of hypothesis testing and control variable strategy.

Children who show no indication of understanding hypothesis testing in Year 5 (9-10 years of age) might have a weakness in a number of cognitive systems, including the statistical learning system (extraction of regularities) involved in grammar acquisition and /or the working memory system.

Remaining Questions

? Could language instruction in hypothetical conditional sentences also help children form the understanding of scientific principles?

? Can children who are hindered by the slower development of their general reasoning (and possibly a number of other cognitive systems) be helped to overcome their limitations by certain type of instruction?

? What type of instruction would be required for this?

Suggestions:

- Using simple language and short sentences
- Using real-life analogies
- Using examples and analogies based on popular cartoons, games, stories
- Presenting principles with props and allowing children to handle them themselves.
- Using virtual environments for children familiar with computers (that would allow to present a greater variety of situation in a classroom setting).

References

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