Children's Strategy Use in Playing Strategic Games

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Development of Strategic Play

- What are differences in strategies?
- What cognitive abilities are related to strategy use?

Strategic Game

Hedden & Zang (2002):
Stackelberg game

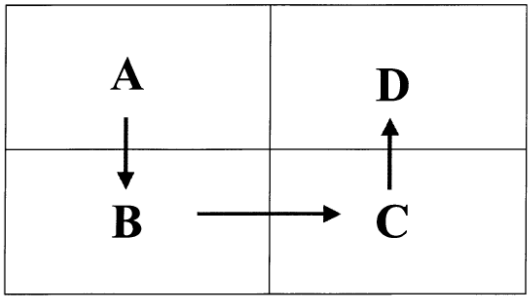
"A knows that I will play X,
so A will play Y"

Player I's Payoffs

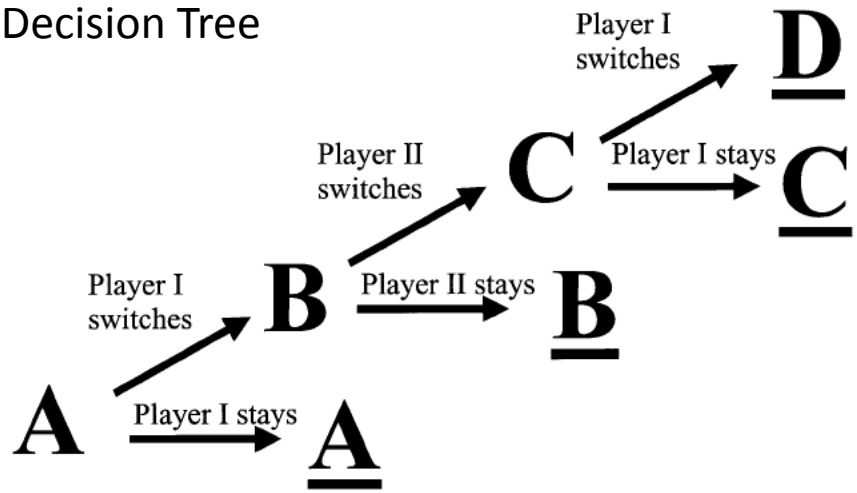
3	4
1	2

Player II's Payoffs

1	2
3	4



Decision Tree

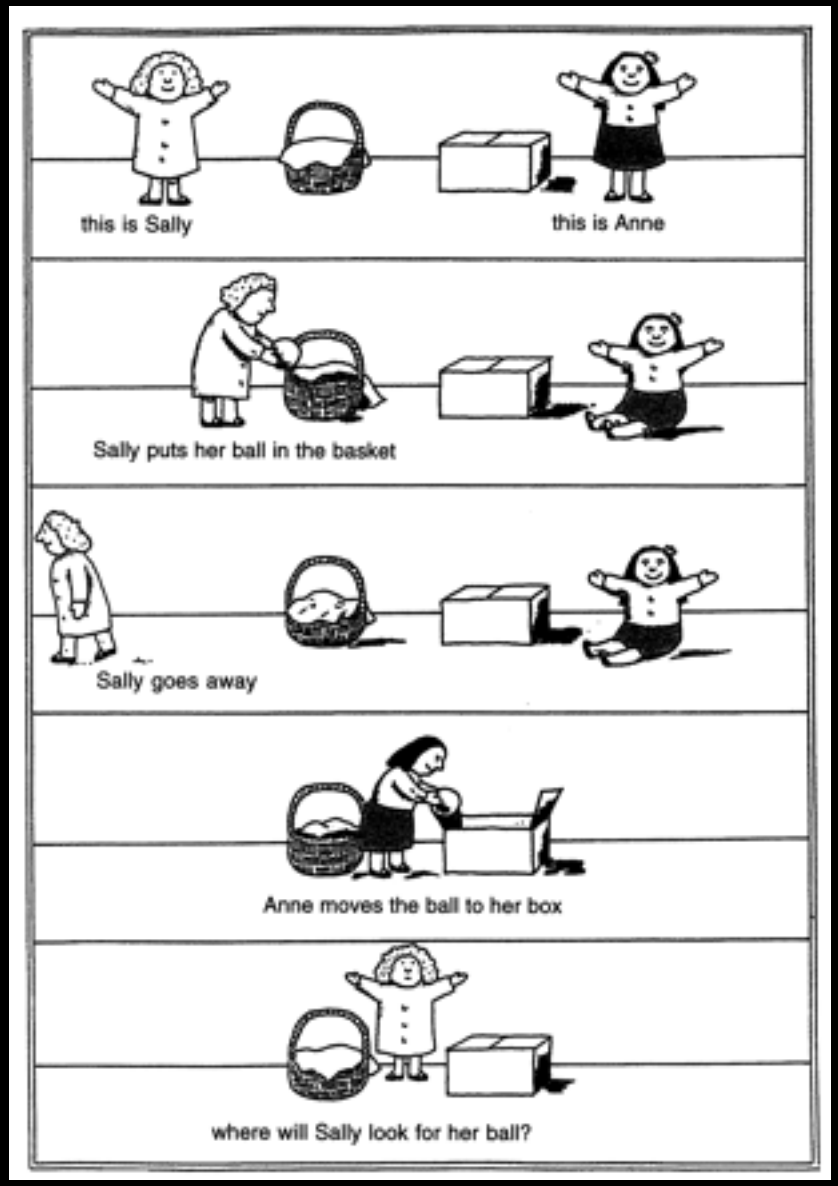


Theory of Mind

- Thinking about other peoples and one's own beliefs or intentions
  - "The other person beliefs X"
  - False belief test, appearance-reality tasks

- Cognitive abilities
  - Working memory
  - Inhibitory control
  - Control for verbal abilities, intelligence and age!

  Carlson et al., 2002, 2004; Wellman, 2001; Miller, 2009.


this is Sally
this is Anne
Sally puts her ball in the basket
Sally goes away
Anne moves the ball to her box
where will Sally look for her ball?

Flobbe et al. 2008, 2nd order

"The other person (A) plays X"

"A knows that I will play X, so A will play Y"

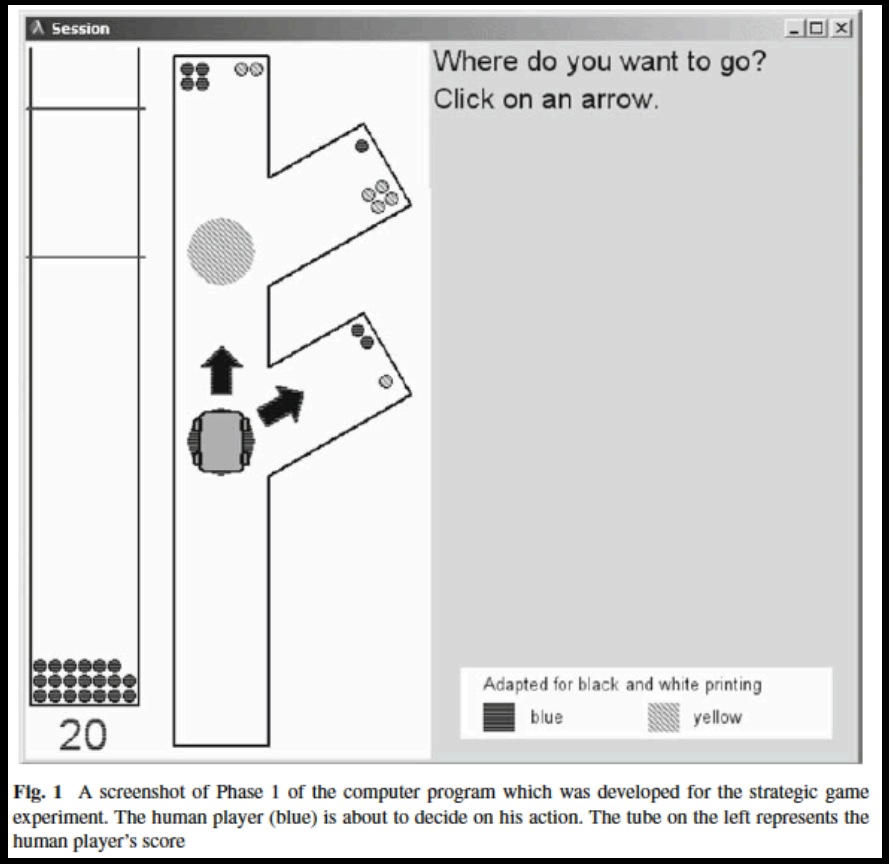


Fig. 1 A screenshot of Phase 1 of the computer program which was developed for the strategic game experiment. The human player (blue) is about to decide on his action. The tube on the left represents the human player's score

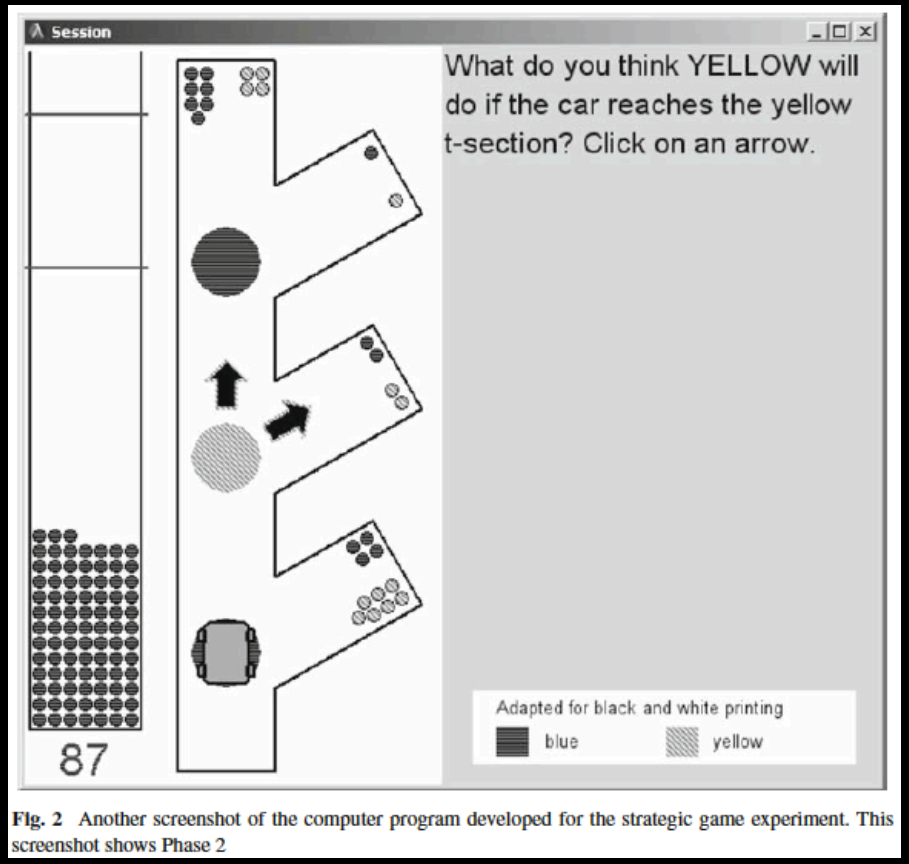


Fig. 2 Another screenshot of the computer program developed for the strategic game experiment. This screenshot shows Phase 2

Flobbe et al., 2008

- False belief task
  - Sullivan et al.'s (1994) 'Birthday Puppy' story
- Sentence comprehension task
  - Speakers need to reason about the hearer’s alternatives

- First order reasoning
  - 55% of the 8 to 10 years old children, > 83% corr.
- Second-order reasoning
  - These 55% children show above chance level performance

- No relation between tasks

Development of Playing Strategic Games

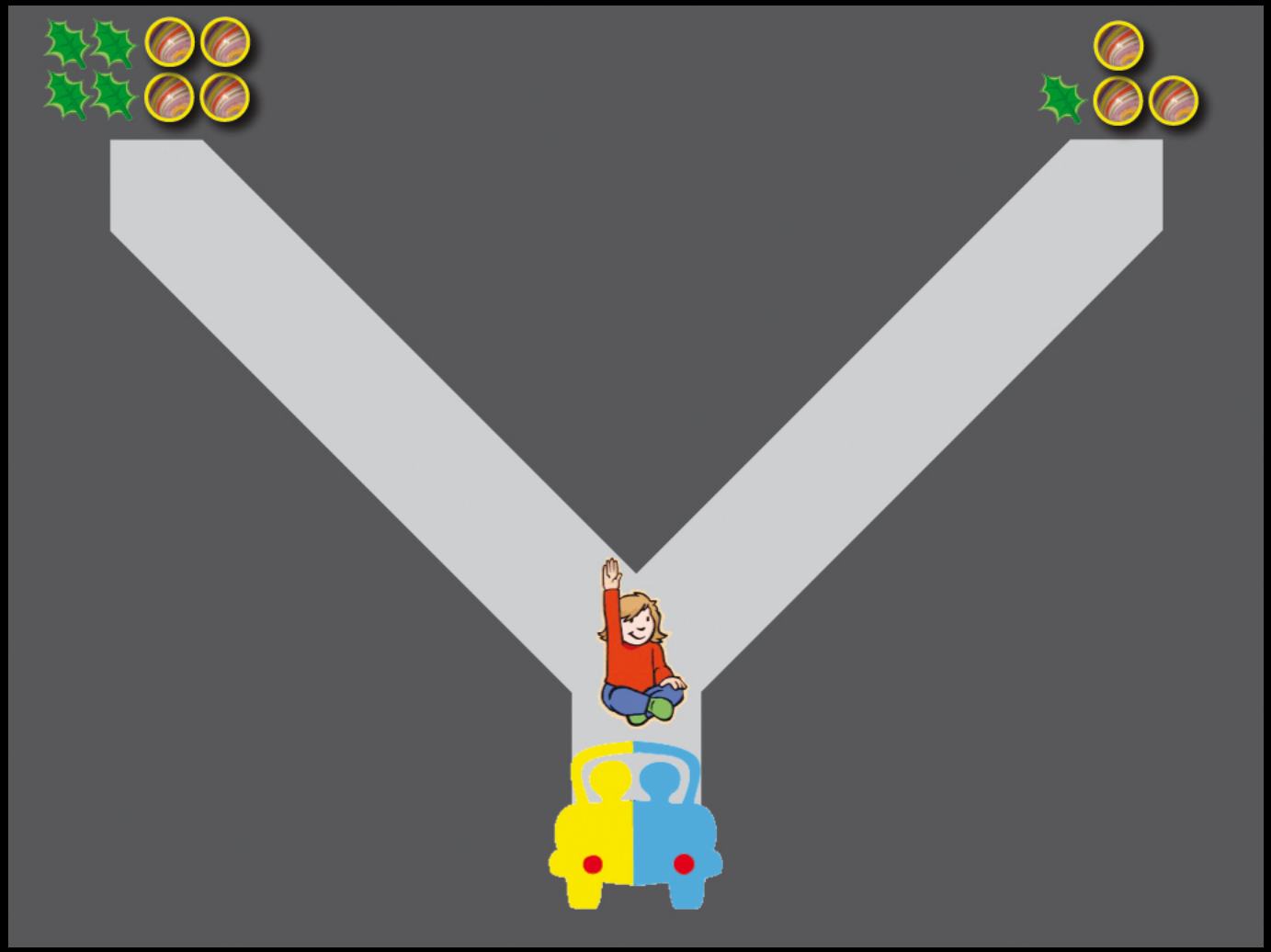
- What strategies do children apply?
  - Strategy analysis
- Relation to Cognitive Abilities
  - Theory of Mind
  - Working Memory
  - Correction for age, verbal abilities, general intelligence

Method

Participants

- 129 children in the age range of 5 to 12 years
  - Traveling game
    - Zero order
    - First order
    - Second order
- (Out of the 129) 49 children (4 and 6 years old)
  - IQ: Raven Progressive Matrices A, B, C
  - Verbal ability: TAK – sentence comprehension
  - WM: digit span forward, backward
  - ToM: Two stories (Flobbe, et al., 2008; Tager-Flusberg and Sullivan, 1994)

Traveling Game, zero-order

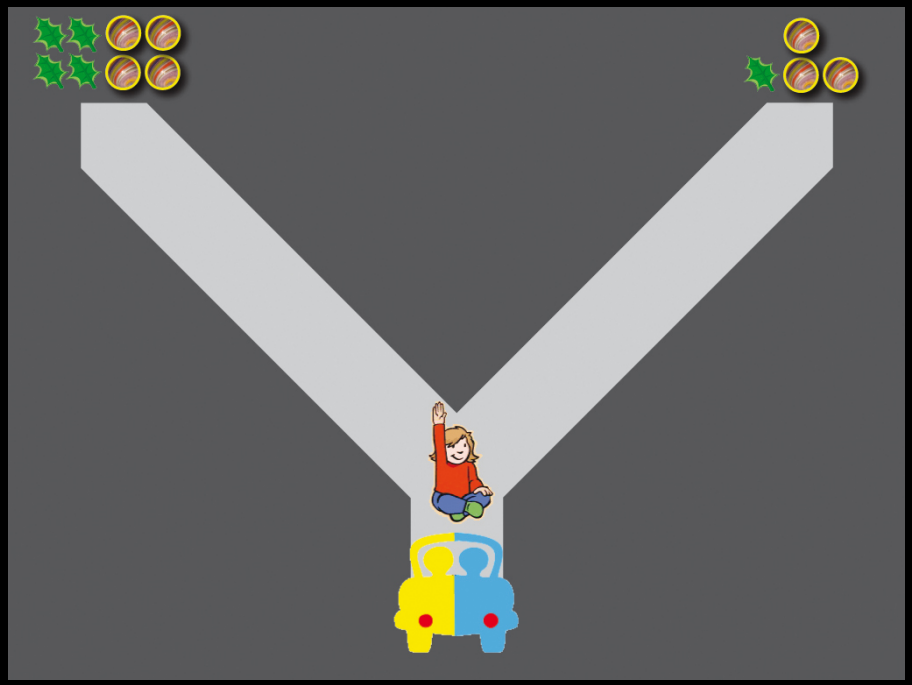


Test Design

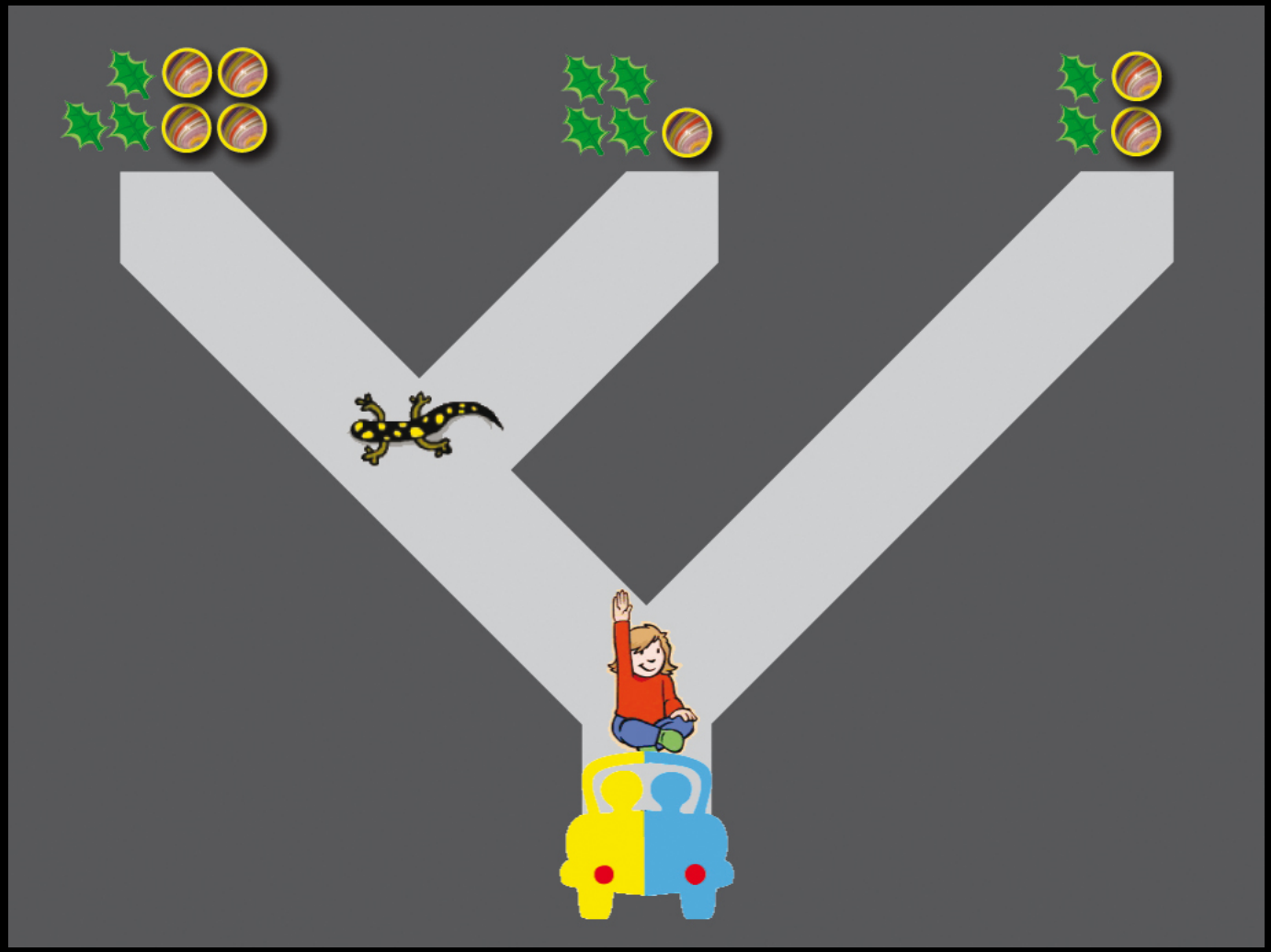
Expected Strategies

- 0-A: optimal strategy
- 0-B: choice for largest sum leafs+marbles
- 0-C: choice for largest relative gain

	Item types	
	I	II
0-A:	1	1
0-B:	0	1
0-C:	1	0



Traveling game, First-Order

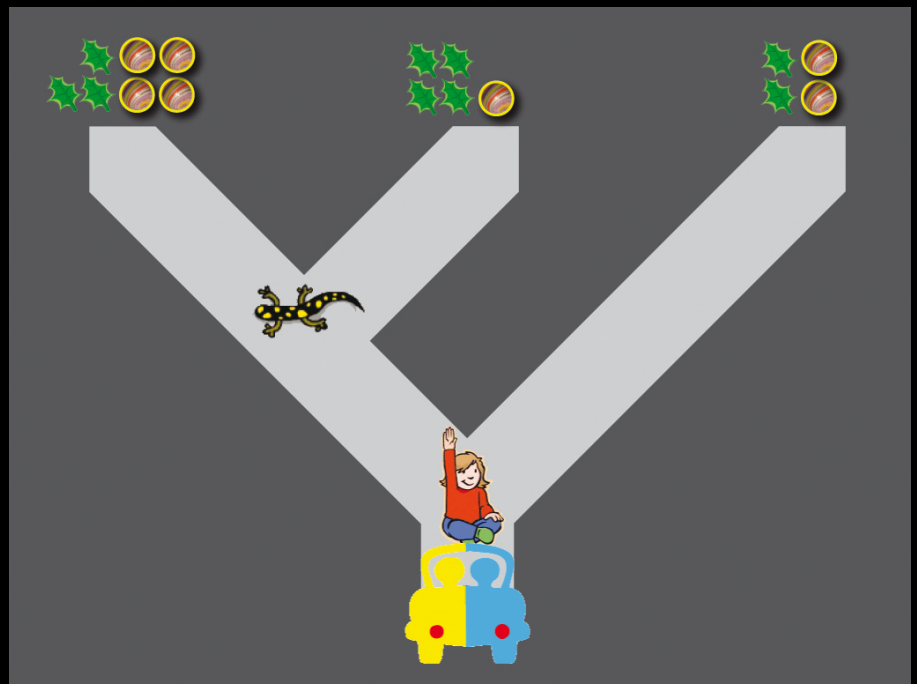


Test Design: First Order

Expected Strategies

- 1-A: optimal strategy
- 1-B: choice for largest relative gain
- 0-A: zero-order largest gain
- 0-B: zero-order largest sum
- 0-C: zero-order largest relative gain
- 0-D: go directly to the right

	Item types		
	I	II	III
1-A:	1	1	1
1-B:	0	1	1
0-A:	1	0	1
0-B:	1	0	1
0-C:	0	0	1
0-D:	0	1	0



Traveling game, second-order

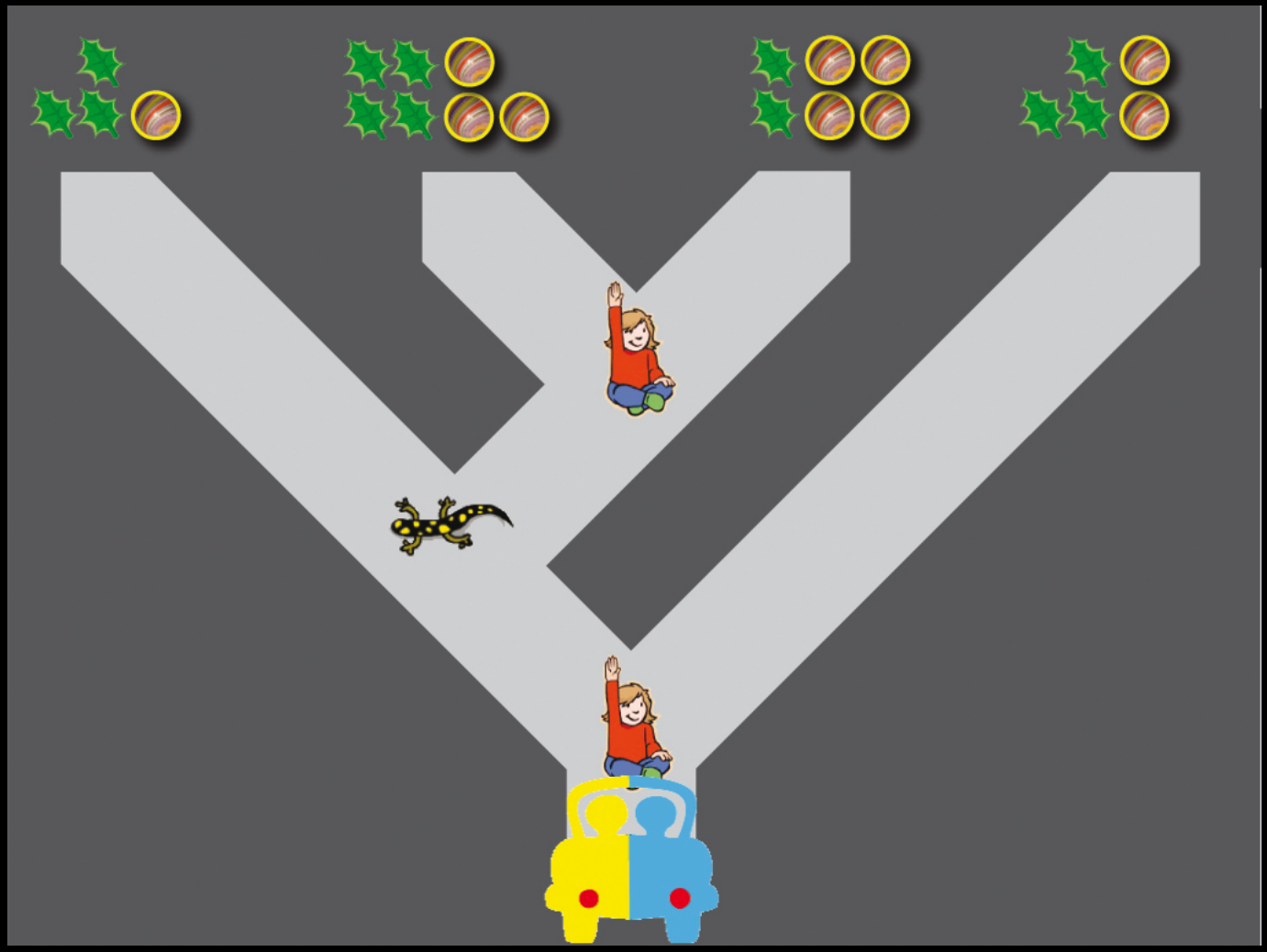


Table A6: Expected accuracy patterns for different potential strategies

	Strategies		
Items	2-A	1-A	1-B
1, 9,4,7	1	1	0
2, 3	1	0	1
5, 6, 8	1	0	0

- 2-A: optimal
- 1-A: first-order with second choice child
- 1-B: first-order without second choice child

Procedure

- Zero-order task
  - 2 example items, scaffolding + animations
  - 9 test items, no direct feedback/animations
- First-order task
  - 3 example items, scaffolding + animations
  - 15 test items, no direct feedback/animations
- Second order task (only after first-order criterion)
  - 3 example items, scaffolding + animations
  - 9 test items, no direct feedback/animations

Results traveling game

- Mean scores
  - Above chance level for 0-, 1st order task ($t(128) = 40.1$, $p < .001$; $t(128) = 10.6$, $p < .001$).
  - Not above chance level 2nd order task ($t(54) = 1.6$, $p = .06$)
- 55 children (43%) past first-order task
  - Mean age = 9.8 (1.96)
- Strategy Analysis, separately per task

Strategy Analysis: Pattern Matching

- Siegler (1981), most cases in developmental psychology and other behavioral studies
- Pattern Matching
  - Matching observed response patterns with expected patterns with criterion for minimal match
  - Criterion is e.g., minimum of 85% match
- Example:

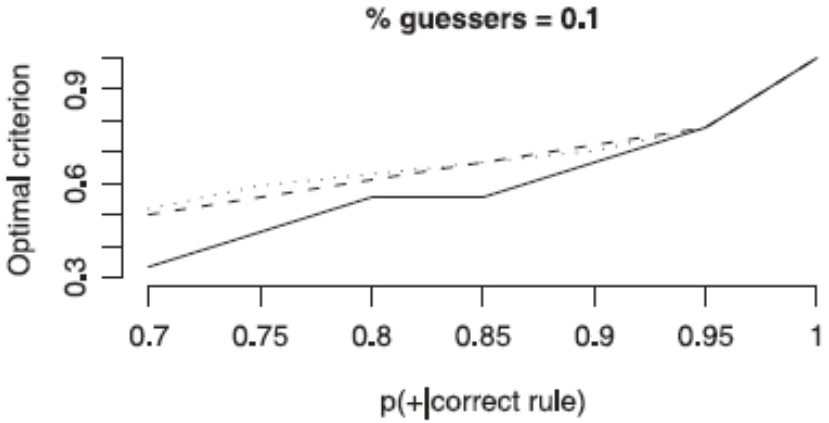
  Participant x observed scores:
  - Type I items: .90
  - Type II items: .15

Strategy 0-C
(largest relative gain)
Mismatch = .125

Latent Class Analysis (McCutcheon, 1987) Statistical Test for Strategies

Problems of Pattern Matching

- Many factors effect optimal criterion
  - # Items
  - Set of Expected Rules
  - # Guessers
  - Accuracy of rule-application
- No criterion for optimal model
  - Most parsimonious model that fits the data well



Solid line = 9 items, striped line = 18 items, and dotted line = 27 items

Advantages of Latent Class Analysis

- Unexpected rules are detectable
- Minimizing False Positives
- Statistical tools for fitting models and model selection

Der Maas, H. L. J. van, & Straatemeier, M. (2008). Developmental science, 11(4), 449-53.

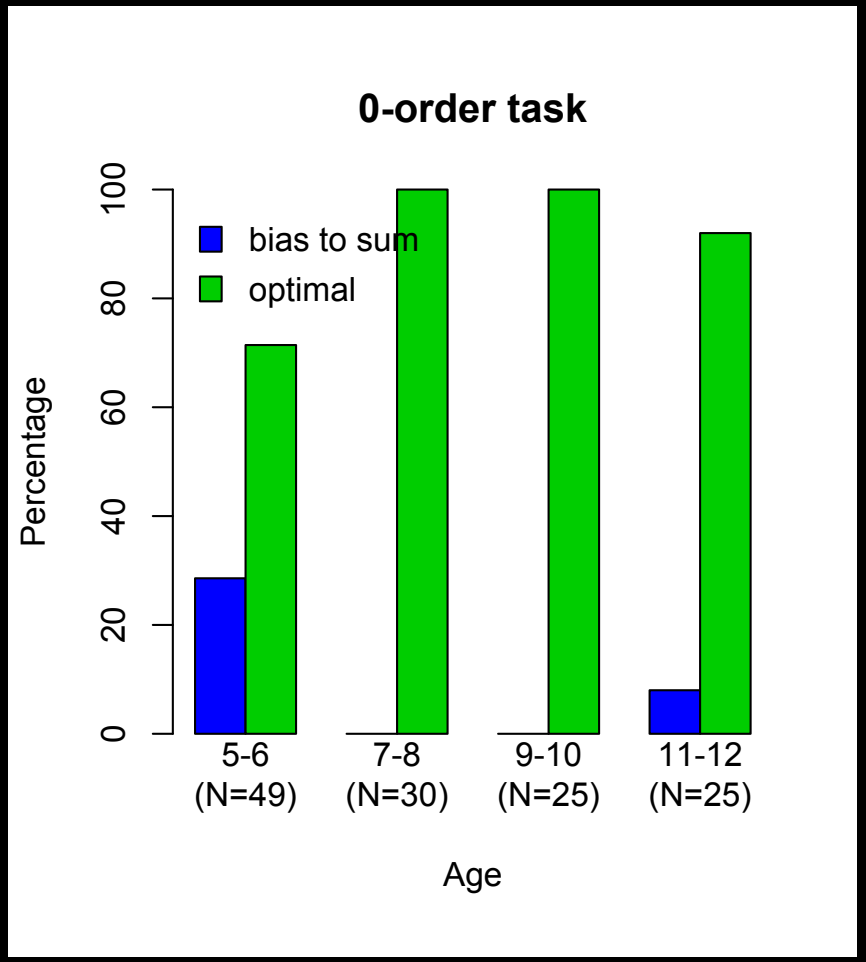
Strategies zero-order task

Table 2: Resulting models from latent class analysis.

	prior	conditional probabilities	
zero-order items		type 1	type 2
bias to sum	.17	.62	.75
optimal	.83	.98	.99

Relation to Age

- Strategies for the zero-order task were related to age
  (Wald test, p = .002)

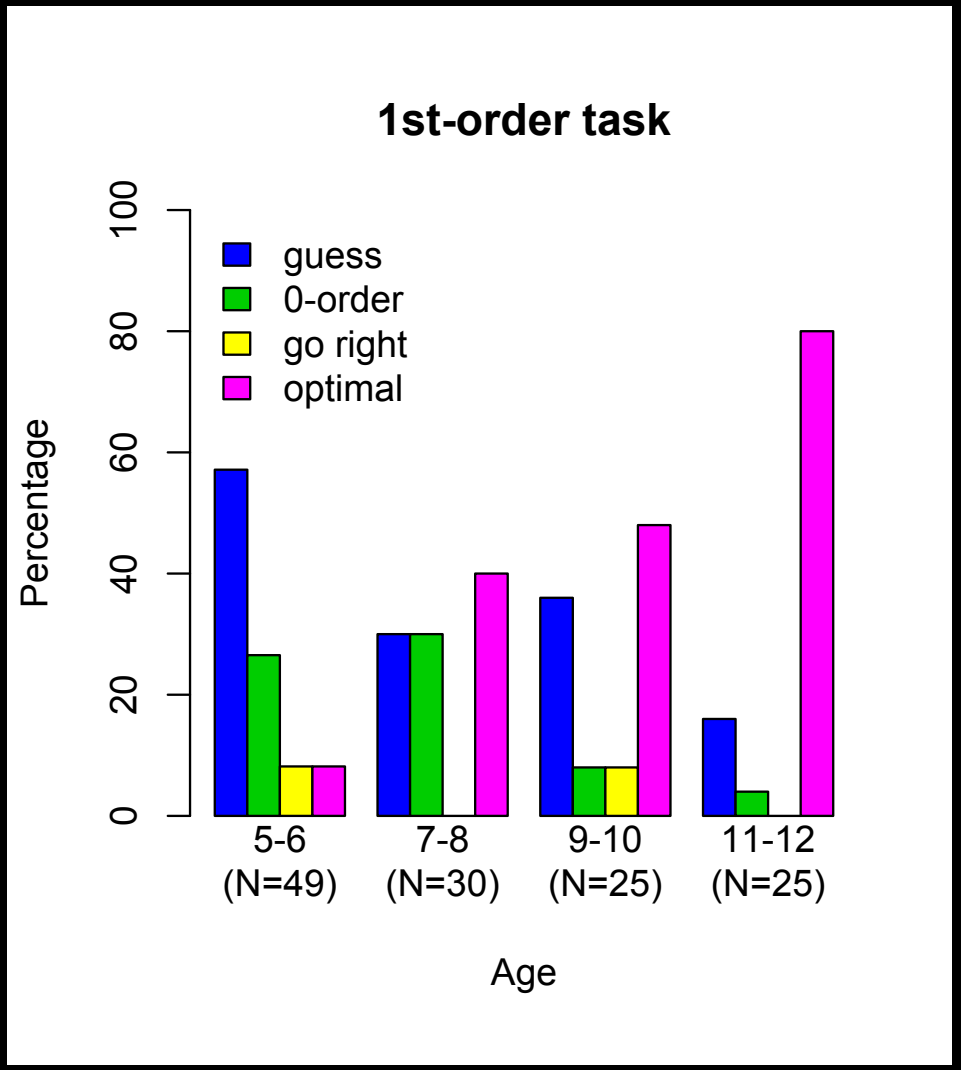


Strategies first order task

first-order items		type 1	type 2	type 3
guess	.39	.62	.47	.79
0-order	.19	.96	.04	.96
go right	.04	.03	.97	.03
optimal	.38	.94	.94	.94

Relation to Age

- Strategies for the first-order task were related to age (Wald test, p = .001).



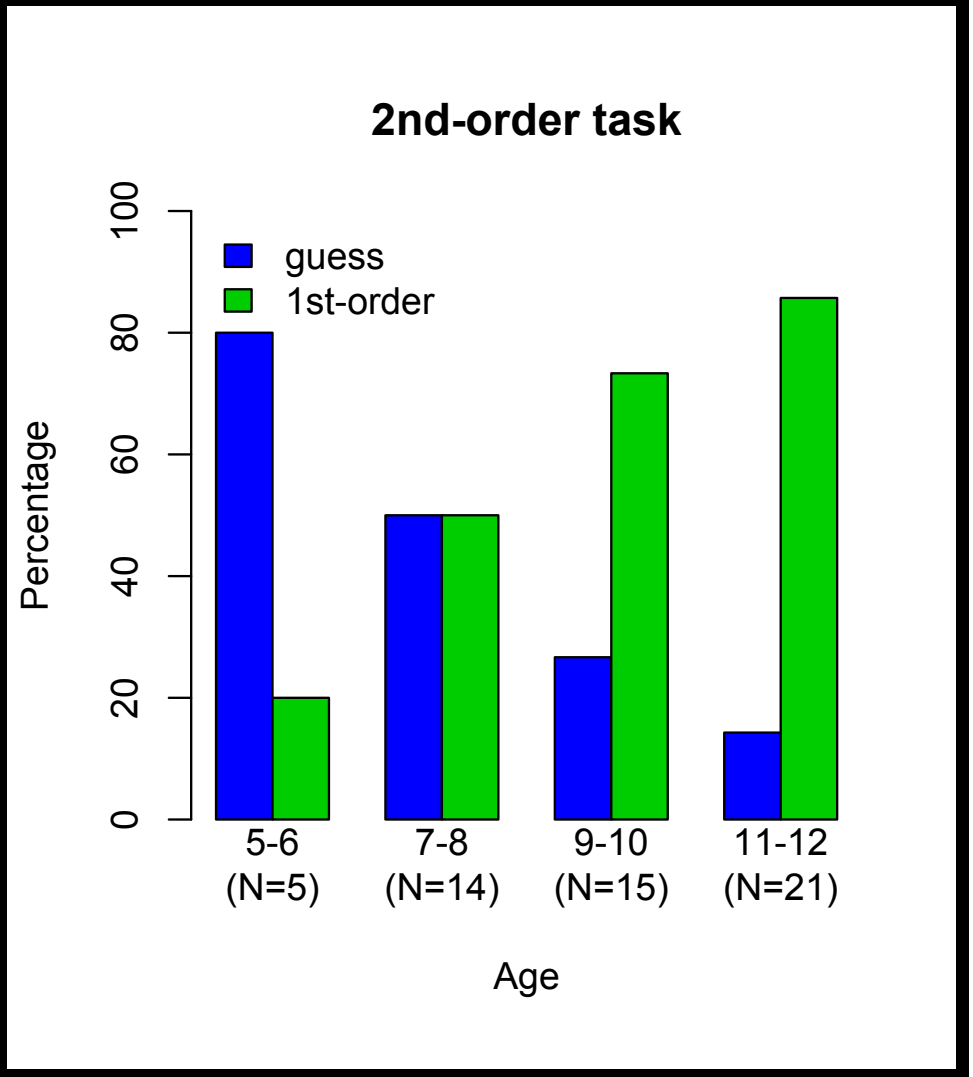
Strategies second order task

second-order items		type 1	type 2	type 3	type 4
guess	.44	.5	.5	.5	.5
first-order	.56	.5	1	.5	.5

- Type 2 items: only correct for first-order without second choice for the child.

Relation to age

- Strategies for the second-order task were related to age (Wald test, p = .005).



Mean Scores

Scores above chance level depends on

- Items in the task
- Strategies used

Table 1: Mean scores for the three reasoning tasks per strategy

Task	S1	S2	S3	S4	All
0-order	0.66 (0.12)	0.98 (0.05)			0.94 (0.12)
1st-order	0.58 (0.16)	0.54 (0.05)	0.51 (0.08)	0.94 (0.06)	0.70 (0.22)
2nd-order	0.42 (0.16)	0.60 (0.17)			0.54 (0.19)

Cognitive tests

- Correlations after correcting for age and verbal ability
- ToM and
  WM: r = .32, p = .02
  IQ: r = .16, p = .005

Table 3: Summary data cognitive tests

Task	5 years		6 years	
	mean	sd	mean	sd
ToM	4.80	1.96	5.92	1.44
ToM1	2.65	1.18	2.92	0.74
ToM2	2.15	1.14	3.00	1.02
DS	5.90	2.05	7.42	1.58
RPM	13.30	4.50	15.88	4.23
Tak	21.85	3.69	24.77	2.39

Strategies and Cognitive Abilities (5 and 6 years old, N = 49)

- Zero-order strategies
  - Only age has a unique contribution
    Logistic regression: coeff. = .1, p = .047
- First-order strategies
  - Only WM has a unique contribution
    Logistic regression: coeff. = .59, p = .017

Conclusion

- Optimal and suboptimal strategies in strategic games are related to age.

- Strategies first-order reasoning
  - Not directly related to ToM
  - Related to WM

Discussion

- How to increase children's abilities in complex reasoning task?
  - Above chance level performance is not conclusive about quality of reasoning (0, 1st, 2nd order).
  - Scaffolding worse performance than short training?
    - Note developmental differences in feedback learning
    - Training in Rekentuin (Mathsgarden)
- Same kind of abilities underlying false belief ToM and playing strategic games?
  - ToM not directly related
    - Static versus dynamic opponent
  - WM important
    - Inhibitory control not measured (pitty!)