Children's reasoning about hypothetical interventions to complex and dynamic causal systems

Angela Nyhout[1,2], Hilary Sweatman[3], & Patricia A. Ganea[1]

[1]Dept of Applied Psychology & Human Development, University of Toronto; [2]School of Psychology, University of Kent; [3] Department of Neurology and Neurosurgery, McGill University

Background

Thought experiments

- Thought experiments are considered a common tool in science education (Gilbert & Reiner, 2000), and may support the learning of complex concepts.
- Our interest in the current study was thought experiments in which the learner imagines *counterfactual* interventions to a causal system.

Counterfactual Reasoning

- Most studies of the development of counterfactual reasoning have focused on *single occurrences* involving *agents* in *simple cause-effect relations* (e.g., Harris et al., 1996; Nyhout et al., 2019; Rafetseder et al., 2013).
- Studying children's ability to consider other types of causal systems counterfactually is critical to theoretical accounts of causal learning (e.g., Woodward, 2003).

Are children who have learned about a dynamic causal system able to reason about counterfactual interventions to the system?

Participants

Experiment 1: *N* = 72 : 24 5-year-olds (*M* = 5.48, *SD* = 0.29), 24 6-year-olds (*M* = 6.46, *SD* = 0.29), and 24 7-year-olds (*M* = 7.44, *SD* = 0.30).

Experiment 2: *N* = 72: 24 5-year-olds (M = 5.43, SD = 0.33), 24 6-year-olds (M = 6.57, SD = 0.34), and 24 7-year-olds (M = 7.45, SD = 0.34).

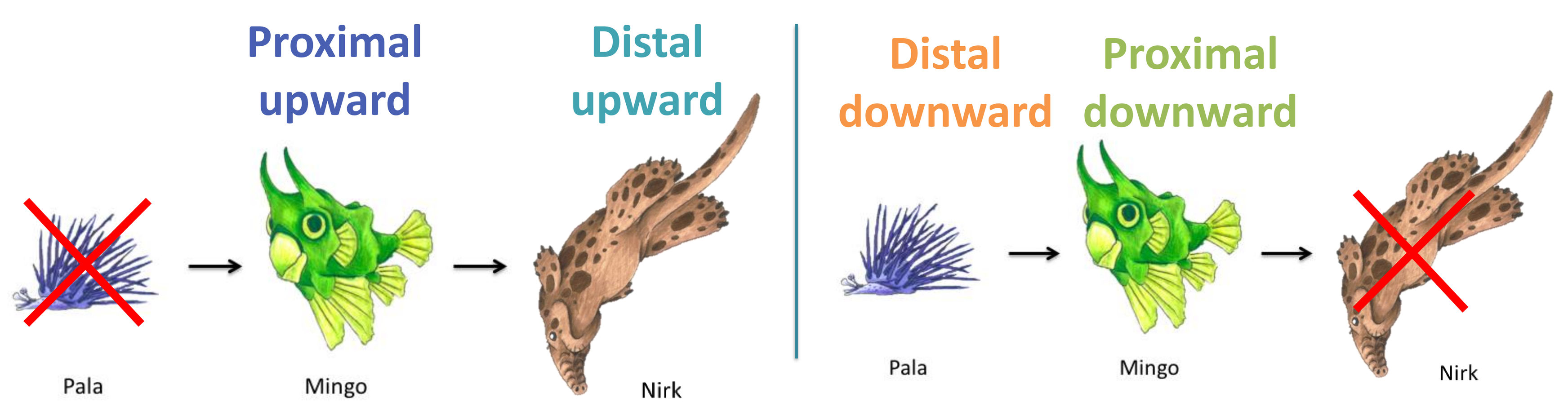
Method

Introduction of each ecosystem *(with accompanying pictures)*

This is a pretend pond. There are lots of palas in the pond. Mingos eat palas. Nirks eat mingos.

Intervention question *(2 per ecosystem, sample images below)*

If there were no more [palas/nirks], would there be more, less, or the same amount of…



Example of images shown while intervention questions were asked about the pond biome

Participants were presented with novel ecosystems, each with a linear food chain containing 3 animals. Children first answered causal questions about which animal eats which (all children answered correctly). They were asked about the impact of the removal of <u>one</u> animal on each of the remaining two (***intervention questions***).

Experiment 1

Children learned about 4 ecosystems (pond, ocean, desert, forest) and were asked about the impact of the removal of either the first or third animal per ecosystem.

Experiment 2

Children were given more detailed instruction about the features and constraints of 2 ecosystems (pond and island) and were asked about the impact of the removal of either the first or third animal per ecosystem. Study was conducted online due to pandemic.

This design allowed us to compare children's responses to ***intervention questions*** along 2 orthogonal variables: **Proximity** (Proximal or Distal) and **Direction** (Upward or Downward).

Analyses

- Generalized estimating equation with binomial probability distribution, and intervention question score (0-1) as the dependent measure.

Experiment 1

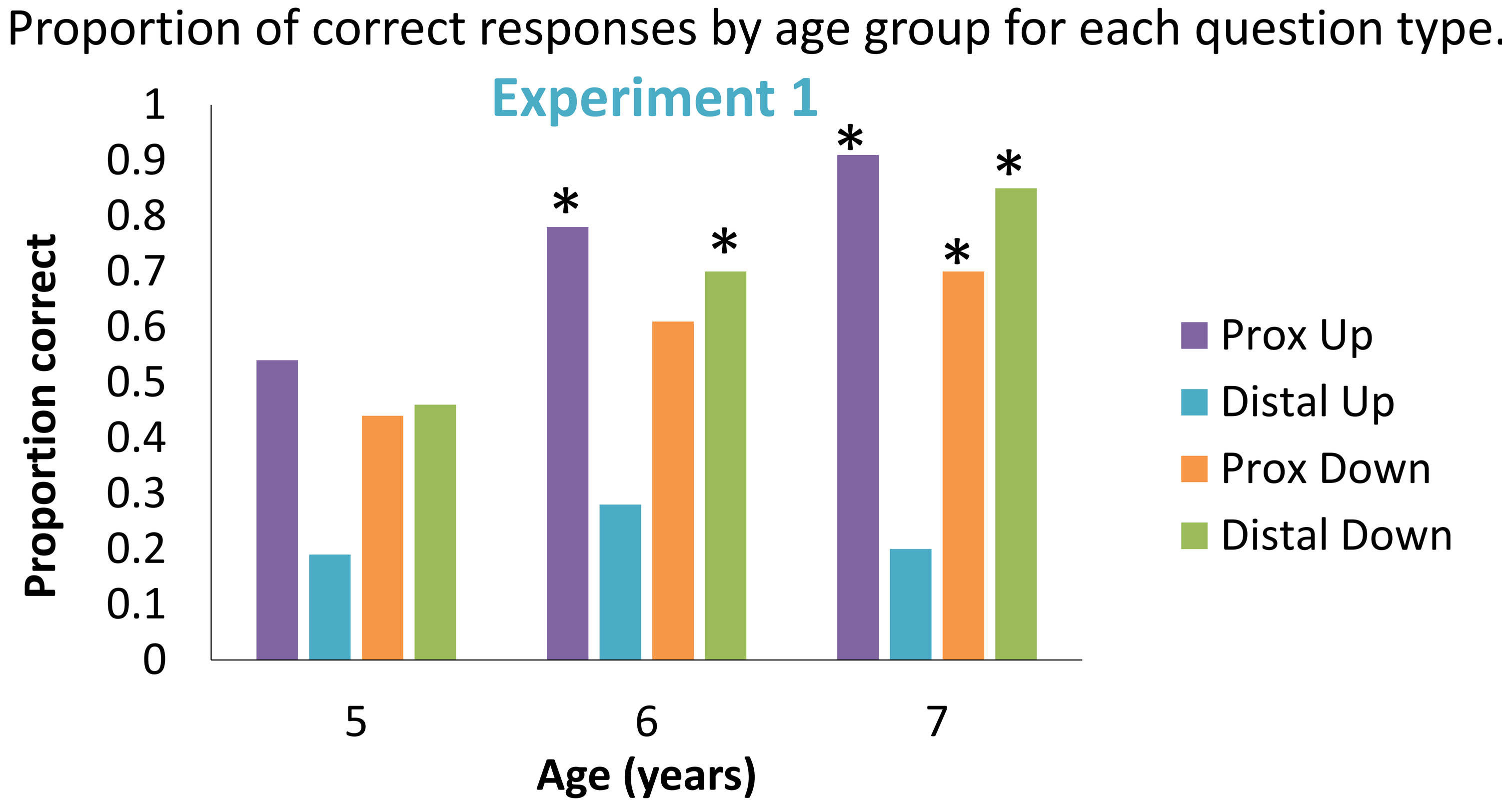
- Predictors: age group (between), and proximity, direction, and presentation order (within-subjects predictors). Order isn't discussed in the reported results as it wasn't a significant predictor.

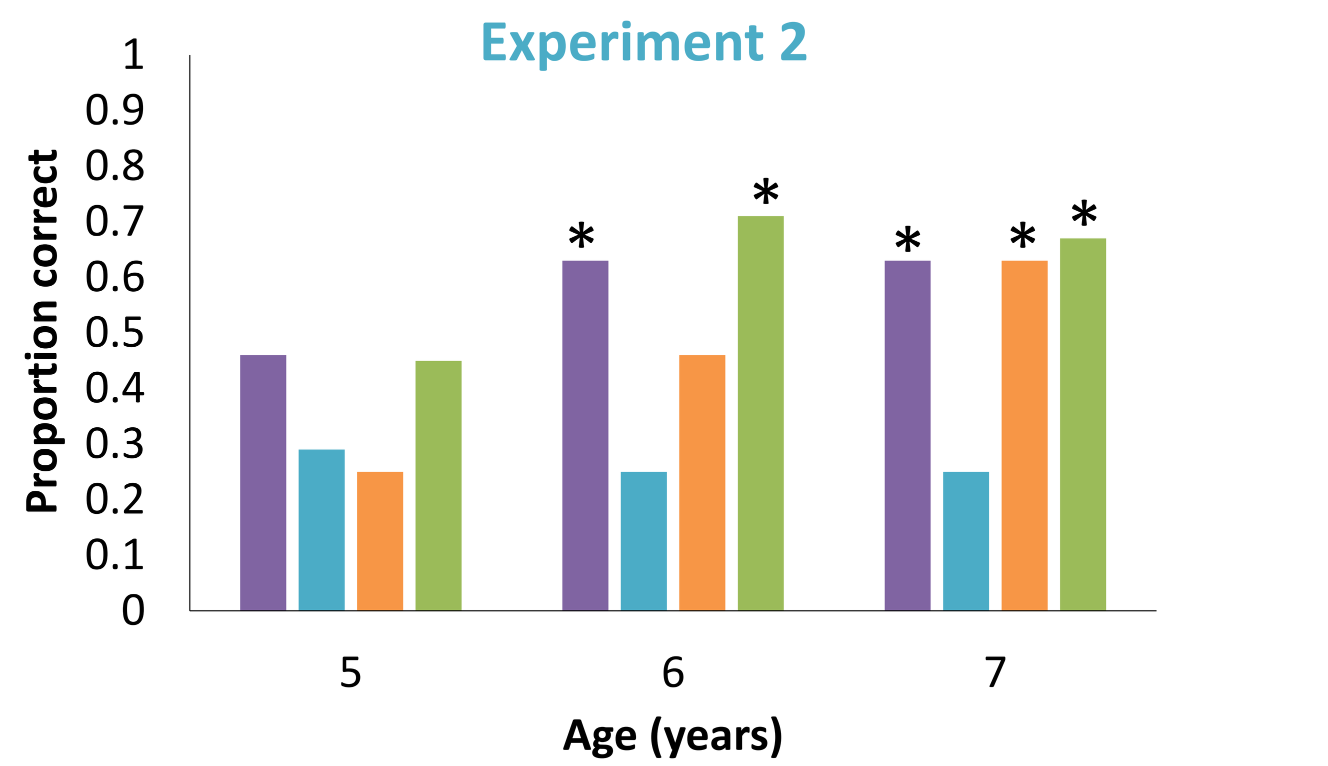
Experiment 2

- Predictors: age group (between), proximity and direction (within-subjects predictors).

Results

Proportion of correct responses by age group for each question type. Asterisks denote differences from chance .





- Age group was a significant predictor, Wald χ2((2) = 12.94, *p* = .002, with 6- and 7-year-olds performing significantly better than 5-year-olds, *p* = .027 and < .001, respectively. Proximity was marginally significant, *p* = .054. Direction was significant, B = 2.94, SE = 0.76, Wald χ2(1) = 15.00, *p* < .001. Children scored higher on downwards items than on upwards items.
- The proximity x direction interaction was significant, B = -4.55, SE = 0.98, Wald χ2(1) = 21.53, *p* < .001. Children's accuracy was significantly lower for *distal upwards* questions than the other three question types, *ps* < .001. Performance differed significantly between *proximal upwards* and *proximal downwards* questions, *p* = .007.

- Age group was a marginally significant predictor, Wald χ2(2) = 5.80, *p* = .055, though none of the age groups differed significantly from each other. Proximity was not a significant predictor, *p* = .781. Direction was marginally significant, Wald χ2(1) = 3.59, *p* = .058. Children scored higher on downwards items than on upwards items.
- The proximity x direction interaction was significant, Wald χ2(1) = 18.03, *p* < .001. Children's accuracy was significantly lower for *distal upwards* questions than all other question types, *ps* < .033.

Conclusion

- Children's ability to reason about counterfactual interventions to dynamic causal systems develops between the ages of 5 and 7.
- Although 5-year-olds correctly answered causal questions about the systems, they did not answer counterfactual questions at a level significantly above chance, suggesting a dissociation between causal and counterfactual reasoning.
- Six-year-olds' performance was mixed, and 7-year-olds performed with a high degree of accuracy, except on distal upwards questions.
- Methodological changes in Exp 2, in which children were given more information about the food chains did not improve performance, suggesting it is the ability to think counterfactually about dynamic biological causal systems that improves in this age range.
- The ability to engage in counterfactual thought experiments like those in the current study may contribute to the understanding of complex concepts, such as natural selection and climate change.

We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) and Social Sciences and Humanities Research Council of Canada (SSHRC).