Research Plan: Testing a Violation-of-Expectation Account of Counterfactual Thinking Development

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Introduction

- For years, studies on the emergence of counterfactual reasoning – imagining how the past could have been different – have yielded contradictory results. Some have suggested that 4-year-olds can engage in mature counterfactual reasoning1, while other studies suggest this higher-level reasoning skill doesn’t emerge until as late as 12 years of age2.
- We propose that counterfactual reasoning elicited by expectancy violation – as opposed to elicited by a counterfactual test question (prompted one) – is the earliest emerging form of counterfactual reasoning.
- Expectancy enables humans to create detailed representations of the future3. In our model, we claim that the discrepancy between a prior expectation and expectation-disconfirming part of reality will spontaneously trigger people to engage in counterfactual reasoning.

Aim and Predictions

- We aim to develop a counterfactual model centred on the violation-of-expectation paradigm and to explore when counterfactual reasoning emerges in development.

We hypothesise that:
1. Children who encounter an unexpected event will be more likely to reference its expected counterpart when asked to describe what happened and what could have happened, especially when the outcome valence is negative.  
2. Prediction errors will result in increased pupil size (objective measurement of surprise), and pupil dilation will predict reference to prior expectations.

- Design
All participants will be presented with 4 trials (fully within-subject design). The outcome valence will be manipulated in a fixed order (positive-negative-positive-negative) but the status of prediction error (expected vs unexpected) in a pseudo-randomized order. See Figures to right.

- Measurements
At the end of each trial, all participants will be asked a series of questions:

We will record participants’ pupil size over the task.
We will also measure their retrospective eye movements when they are asked test questions. We will use a blank-green screen at this phase.

Method

- Participants: Target N = 45 3-5-year-old children to establish task viability.
- Study Materials: Children will play a game of chance consisting of 4 trials. They will have a chance to win a different kind of toy as an award (e.g., a teddy bear, a car, a ball) at the end of each trial. For example, a bear will be hidden behind one of the two boards, and children will be told that if they hit the board with the bear behind it, they will win the bear. They will then choose whether to shoot an arrow left or right.

We will stop the video after the arrow begins to move in the direction they choose and ask prediction questions:
- Which way will your arrow go?
- Which board will your arrow hit?

- Analysis Plan
We will code their answers according to whether they refer to their prior expectations or not. If they reference their prior expectations after being asked spontaneous (D1) and prompted counterfactual test questions (D2), they will get 1. Otherwise, they will get 0.

- Behavioural Data Analysis
Because of the repeated measurements and dependency in our dataset, we will use generalized linear mixed-effect models with binary error distribution (GLMM). We will run separate GLMMs for spontaneous and prompted counterfactual test questions (dependent variables). Our full models will include expectancy, outcome valence, age and their interactions as fixed effects and participant ID as a random effect.

- Pupil Dilation Data Analysis
First, we will calculate normalised pupil size changes for each participant and for each trial type. We will then run t-tests to check for significant differences in mean changes between trials. We will use the GLMM models we have planned for behavioural data analysis, but instead of expectancy, the models will include changes in pupil size.

- Exploratory Data Analysis
As an exploratory analysis, we will also analyse which part of the screen participants are more likely to look at while answering test questions (retrospetive eye movements).

References


diagram

Figures

- Remember Question
- Did you get the [toy]?
- Spontaneous Counterfactual Questions (D1)
  - Can you tell me what happened from the beginning to the end?
  - Why did you win/not win the [toy]?
- Prompted-Counterfactual Question (D2)
  - How could you have won/lost?

Analysis Plan

- No Prediction Error
- Prediction Error

Summary

- We propose a model for early emerging of counterfactual reasoning driven by violation-of-expectation:

1. Expectation Phase
   - The arrow will move to the left. (Imagining expectation of future)

2. Activation Phase
   - The arrow should have moved to left (Prior expectation)

3. Generation Phase
   - Arrow unexpectedly turned to right (Unexpected part of reality)

4. If the arrow had moved to left, I could have won the bear.

- Representation of unexpected reality and its expected counterpart will spontaneously appear in children’s minds, and prior expectations will be readily available as a counterfactual antecedent.
- We argue this cognitive process will decrease demand on executive functions via two processes: (1) children spontaneously keep reality and the expectation (false representation) in their mind (creating lower demands on working memory); (2) children will be less likely to be affected by reality bias because the expected reality will become the counterfactual antecedent.