Changing Facts in Children's Counterfactual Reasoning

Ioana Grosu and Ailís Cournane

1. Introduction

Counterfactual reasoning involves thinking about possibilities incongruous with the actual world, and being able to choose among them in a principled manner (Lewis (1979), i.a.). Counterfactual language typically involves a conditional construction, with an antecedent (e.g., 1) that is overtly false in the actual world, and a consequent (e.g., 1a. or 1b.) which describes the world given the antecedent.

(1)	If cats had wings...		antecedent
	a.	...they would fly.	consequent - More plausible
	b.	...they would be insectivores.	consequent - Less plausible

In the actual world, cats having wings is false. Yet, when we entertain this falsity, we have clear judgments about which possibilities are more likely to arise (1a $>$ 1b). Children below the age of 8 show various difficulties with this kind of reasoning (e.g., Nyhout and Ganea, 2019; Rafetseder et al., 2010).

In this study, we examine children's non-adult answers to counterfactual questions: When children's responses diverge from those of adult controls, what kinds of changes do they allow to their model of the actual world? Prior literature on children's counterfactual reasoning has mainly focused on whether (e.g., McCormack et al., 2018; Rafetseder et al., 2010) and when (e.g., Nyhout et al., 2019; German and Nichols, 2003) children reason counterfactually, and has also considered whether children use a simpler reasoning strategy, namely *conditional reasoning* (e.g., Rafetseder et al., 2013). We want to know, when children differ, which counterfactual alternatives do they prefer?

To address our research question, we ask 5-to-7-year-old children and adult controls counterfactual questions in the context of a day at the waterpark. We use causal models (Rips, 2010; Hiddleston, 2005; Pearl, 2009) to create scenarios with (a) different facts of the actual world (i.e., the location of a character at the time of questioning), and (b) different rules for each waterpark attraction (i.e., restrictions on how many characters can be in the pool). When adults reason counterfactually, they maintain the facts and the rules of the actual world, as was borne out in our results. An adult-like response, therefore, is parsimonious with respect to the changes allowed from the actual world. Results show that children's responses allow significantly more changes from the actual world. Importantly, non-adult

 Proceedings of the 46th annual Boston University Conference on Language Development, ed. Ying Gong and Felix Kpogo, 270-283. Somerville, MA: Cascadilla Press.

responses primarily involve changing facts, rather than changing the rules given in the scenarios.

1.1. Background

Mature counterfactual reasoning involves three distinct conceptual abilities which children must acquire (Beck et al., 2011). These are the abilities to: (a) generate alternative worlds, which are distinct from the real world, (b) reason over events or states that are explicitly false in the real world, and (c) determine which counterfactual possibilities are closest to the actual world. The latter is referred to as the *nearest possible world constraint*, and is discussed in relation to development in Rafetseder et al. (2010). It can be paraphrased in the following way: Mature counterfactual reasoning involves not only reasoning about which possible worlds are able to be generated, but also which worlds are most similar to the actual world. This constraint is largely based on the similarity principle in Lewis (1979): A counterfactual is true iff the consequent is true in all worlds in which the antecedent is true and that are otherwise most similar to the actual world.

The similarity principle from Lewis (1979) can be readily operationalized in a causal model-based approach. Following work like Hiddleston (2005) and Pearl (2009), we measure similarity based on the changes one makes to the causal structure representing the actual world, in order to precisely measure the nature of children's non-adult answers to counterfactual questions. Similarity is based on the number of causally independent facts which are preserved from the actual world. For a fact to be causally independent it must not be caused by the antecedent facts. To illustrate, we can consider two events (A and B) which both must happen in order for a third event (C) to happen. If A not occurring is our antecedent fact, then C not occurring would be causally dependent. On the other hand, the status of B would be causally independent, since B is not causally related to A in the same way.

To maintain simplicity, we claim that the model which preserves the most causally independent facts is most similar to the actual world model. As is the case in our three-variable example, changing the status of B (the causally independent variable) is not necessary. A minimal change would just involve a change to the status of A (our antecedent), and the resulting change to C. In addition, any changes to the model must also maintain the rules (or laws) of the system. For example, a minimally changed model cannot be one in which A does not happen, but C does happen.

Prior literature (e.g., Hiddleston (2005) claims that counterfactual reasoning involves selecting for the model which is closest to the model of the actual world. The closest model, and therefore the one which we expect adults to select, would be one in which the status of B remains unchanged.

In prior studies on counterfactual acquisition, the focus lies primarily in investigating the age at which children are able to reason over counterfactual possibilities in an adult-like manner. Around 4 years old, children begin exhibiting counterfactual reasoning and can reason over alternatives which are false in the actual world. (e.g., Beck et al., 2011; Kuczaj and Daly, 1979; German and Nichols, 2003; Riggs et al., 1998). Beck et al. (2011) define this more precisely, suggesting that by age 4, children are able to temporarily entertain a false proposition as true.

When does counterfactual reasoning become fully adultlike? Some studies find that counterfactual reasoning develops between the ages of 6 and 12 (e.g., Rafetseder et al., 2013). Other studies find that counterfactual reasoning develops earlier, by around 8 years of age (e.g., Nyhout and Ganea, 2019). Some studies find that it develops even earlier, between the ages of 5-7 (e.g., Beck and Guthrie, 2011; McCormack et al., 2018).

To analyze the age at which children are able to use the nearest possible world constraint, some studies consider children's reasoning about counterfactuals involving *doubly determined events*, or events with two possible causally independent antecedent causes (e.g., McCormack et al., 2018; Nyhout et al., 2019; Rafetseder et al., 2013). Consider the following scenario: a light can be turned on either by using a switch A or a switch B (or both). Currently, both switch A and switch B are flipped up, and the light is on. Now suppose, counterfactually, that switch B was not flipped up. Would the light still be on? Here, the adult-like answer is yes - since we have no reason to change the status of switch A. This answer follows the possible world constraint, since we minimally depart from the actual world.

In a scenario with an identical causal structure Nyhout et al. (2019) found that 8-year-olds leave the outcome unchanged (i.e., say the light would be on) in the case of doubly determined events. Six-year-olds, on the other hand, change the outcome to a significantly greater extent. Rafetseder et al. (2010) use a slightly less complex structure for their scenarios, and also demonstrate that children under age 6 had difficulty with counterfactual reasoning, especially with respect to the closest possible world constraint.

Previous studies have also analyzed whether children reason qualitatively differently from adults, using a simpler Basic Conditional Reasoning (BCR) strategy in their responses. BCR involves reasoning based on observed regularities. For example, in the case where there are two possible causes (A and B) for an event (C), BCR would lead one to conclude that if one cause (e.g., A) does not occur, then C does not occur, because they are following the simpler rule that $\neg A \rightarrow \neg C$ (Nyhout et al., 2019). Rafetseder et al. (2013) test this, by introducing a scenario with two characters, Max and Susie. Both Max and Susie enter a house with muddy shoes, and the floor becomes dirty. Children are then asked what would have happened if Susie had taken her shoes off. Rafetseder et al. (2013) claim that children engaging in BCR would answer that the floor would be clean, because they would draw the overgeneralized conclusion that 'no shoes = clean floor.' BCR is therefore a possible reasoning strategy which results in non-target answers to counterfactual questions. In the present study, we find that children are likely not using BCR in their responses.

In both Nyhout et al. (2019) and Rafetseder et al. (2010) there remains the open issue of the aspects of the counterfactual scenarios that children change. In order to address this issue, we use our causal models-based definition of similarity, which allows us to precisely capture the changes children allow from the actual world when reasoning counterfactually.

Studies have found that the causality and counterfactuality are intrinsically linked in both adult reasoning and in acquisition (e.g., Frosch and Byrne, 2012; McCormack et al., 2011). In Frosch and Byrne (2012), adult participants expressed causal relationships in their paraphrases of counterfactual conditionals. Edgington (2011) argues that causal notions are important in giving an account of adult counterfactual reasoning. Finally, McCormack et al. (2011) show that children's causal judgments are consistent with their counterfactual judgments.

Nyhout et al. (2019) further explore this causal connection in acquisition. They presented 5-to-7-year-olds with stories which had a causally connected and a causally disconnected version. In the connected version, the two possible antecedent events were directly causally related, and in the disconnected condition, the two antecedent events were causally unrelated. Six-year-olds performed better in the connected rather than in the disconnected condition, which raises an important issue: Is their performance due to the increased causal coherence in the connected condition, as the authors suggest? Furthermore, what counterfactual possibilities do children favor, which leads them to non-adult responses to the causally disconnected scenarios? Nyhout et al., suggest that children may posit additional causal connections in certain conditions. However, the nature of these changes to the variable facts and laws which comprise the scenario remains open. We explore this question in the present study.

2. Methods

2.1. Participants

Participants were English-speaking children, 5-to-8-years-old (n = 21, range = 5.2 - 8.9 years-old, m = 6.7 years-old). Children were recruited through online sign-ups.

In addition, we tested adult participants (n = 20). Adults were recruited through online sign-ups, and were required to be over 18 years of age and native speakers of English.

2.2. Materials and Procedure

The stories were presented visually through the screen share feature of Zoom (Zoom Video Communications, 2021). The visual image comprises a platform with a slide that goes into a swimming pool. Drawings of a penguin, giraffe, and crocodile move onscreen, according to the story.

Each test item took about three minutes to complete, including the presentation of the prompt and the participant's response time. The trials were presented to children verbally. Children were tested individually, and test sessions were recorded, given parental consent.

Table 1 provides a sample order for a full testing session, including the training items and test items (two test items for each of the three scenarios).

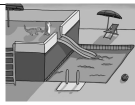
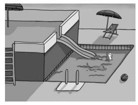
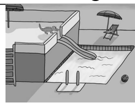
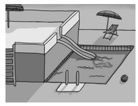
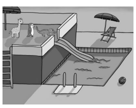
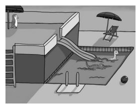
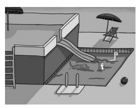
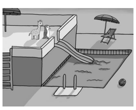
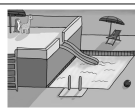
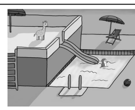
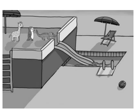
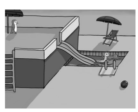
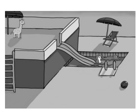
Participants were first given the following short introduction to the characters, accompanying images of the characters: "This is Crocodile. He's a good swimmer, and loves going in the water. He also loves to relax in the shade. This is Penguin. He's also a very good swimmer, and loves going in the water. It doesn't matter to Penguin if the water is really cold. Sometimes, though, Penguin also likes to sit in the shade and relax. Finally, this is Giraffe. He's a pretty bad swimmer, but has a lot of fun in the water. To stay safe, he needs someone in the water in case he runs into any trouble. Since he's really active, Giraffe prefers to be in the water instead of in the shade, whenever it's safe for him. Since they live in different places, Crocodile Penguin and Giraffe don't know each other. But today, they're all at the same park!"

Participants all saw the same two training items. These items were two-variable counterfactual scenarios, with a straightforward causal connection. If participants are unable to understand the training questions, or are unable to provide sufficient justification for their responses, their data is excluded from the study. No participants were excluded in the present sample.

Our stimuli involve three scenarios and four conditions. Each scenario consists of three changeable facts and one primary law. The counterfactual scenarios differ through the laws governing the relationships between variables. The presentation of scenarios was within-subjects, and the presentation of conditions was between-subjects. Each participant was shown all three scenarios, and was presented with two of the four conditions per scenario. Conditions differed by what questions were posed to participants.

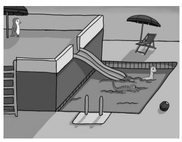
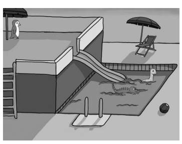
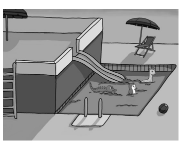
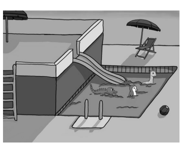
The order within testing blocks was consistent across participants. Participants were always given a question in the Change condition, followed by a question in the Maintain condition. The order in which the testing blocks were presented was counterbalanced. Table 1 shows a sample testing session, with images of the initial setup, the actual world, the law of the scenario, and the counterfactual questions asked.

Table 1: Sample Testing Session

	Setup	Actual World	Question
(I) Training			
1	 Crocodile and Penguin are both good swimmers		If Penguin had decided to stay at the top would Crocodile still have gone down the slide? Adult answer: Yes
2	 Crocodile will not go into a pool with cold water.		If the pool had been cold would Crocodile still have gone down the slide? Adult answer: No
(II) Testing			
Disj.	 Giraffe will go down the slide if crocodile or penguin or both are in the pool.		If Crocodile had decided to stay at the top would Giraffe still have gone down the slide? Adult answer: No
			If Crocodile had decided to stay at the top would Giraffe still have gone down the slide? Adult answer: Yes
Conj.	 Giraffe will go down the slide if the pool is not cold and penguin is in the pool.		If the swimming pool hadn't been cold, would Giraffe have gone down the slide? Adult answer: No
			If the swimming pool hadn't been cold, would Giraffe have gone down the slide? Adult answer: Yes
Excl. Disj.	 Giraffe will go down the slide if crocodile or penguin are in the pool, but not both.		If Penguin had gone down the slide, would Giraffe still have gone down the slide? Adult answer: No
			If Penguin had decided to stay, at the top, would Giraffe have gone down the slide? Adult answer: Yes

For each scenario, the goal is for Giraffe to go down the slide. The counterfactual questions for each testing condition were generated based on whether an aspect of the original scenario needs to change in order for the goal of the scenario to be achieved (e.g., whether in order for Giraffe to slide down, Crocodile would also need to slide down). Table 2 provides the four conditions, using the disjunctive scenario to illustrate, along with the counterfactual questions asked for each condition. The Change conditions require a change to either a fact of the actual world or the law in order for Giraffe to achieve his goal. The Maintain conditions do not. The Agree condition requires the participant to answer “yes” in order for Giraffe to achieve his goal, while the Disagree condition requires the participant to answer “no”. The Agree and Disagree conditions are used to reduce a possible yes-bias among participants and balance for “yes” and “no” responses.

Table 2: Disjunctive scenario conditions

Condition	**Actual World**	**Question**	**To achieve goal**	
			AW	**Answer**
Change Agree		If Crocodile had decided to stay at the top, would Giraffe still have gone down the slide? Adult answer: No	Change: Penguin slides	Yes: Giraffe slides
Change Disagree		If Crocodile had decided to stay at the top, would Giraffe have decided to stay at the top? Adult answer: Yes	Change: Penguin slides	No: Giraffe does not stay at the top
Maintain Agree		If Crocodile had decided to stay at the top, would Giraffe still have gone down the slide? Adult answer: Yes	Maintain: Penguin does not slide	Yes: Giraffe slides
Maintain Disagree		If Crocodile had decided to stay at the top, would Giraffe have decided to stay at the top? Adult answer: No	Maintain: Penguin does not slide	No: Giraffe does not stay at the top

When participants gave non-target responses, we needed to probe why. To ensure accurate coding of changes to laws versus facts, we asked participants about the location of the character not mentioned in the antecedent. For example, in the disjunctive scenario, we asked participants where Penguin would be, following their response about Giraffe's status. If participants moved Penguin, then that meant they changed a fact of the model. If they did not move Penguin, and allowed Giraffe to swim with no animals in the pool, that meant they changed a law of the system.

3. Results

Table 3 provides proportions and counts of target responses by both condition and scenario first for adults (3a) and then for children (3b).

Table 3: Aggregate proportions and counts of adults' and children's target responses by scenario and condition

		Condition	
		Agree (N = 10 participants)	Disagree (N = 10 participants)
Scenario	Disjunction	Change: 1.00 (10/10) Maintain: 1.00 (10/10)	Change: 0.90 (9/10) Maintain: 1.00 (10/10)
	Conjunction	Change: 1.00 (10/10) Maintain: 1.00 (10/10)	Change: 0.80 (8/10) Maintain: 1.00 (10/10)
	Excl. Disj.	Change: 1.00 (10/10) Maintain: 1.00 (10/10)	Change: 0.90 (9/10) Maintain: 1.00 (10/10)

(a) Adults' responses

		Condition	
		Agree (N = 10 participants)	Disagree (N = 11 participants)
Scenario	Disjunction	Change: 0.80 (8/10) Maintain: 1.00 (10/10)	Change: 0.82 (9/11) Maintain: 0.91 (10/11)
	Conjunction	Change: 0.70 (7/10) Maintain: 0.80 (8/10)	Change: 0.45 (5/11) Maintain: 0.91 (10/11)
	Excl Disj.	Change: 0.70 (7/10) Maintain: 1.00 (10/10)	Change: 0.55 (6/11) Maintain: 0.82 (9/11)

(b) Children's responses

Adults performed at ceiling in almost all conditions, with the exception of the Change & Disagree condition. Overall, children responded with more non-target answers than adults, and responded with the greatest proportion of non-target answers for the Change conditions.

We next consider a direct comparison between child and adult proportions of target answers. In Figure 1, we observe that children provided fewer target answers than adults, who performed nearly at ceiling on all scenarios.

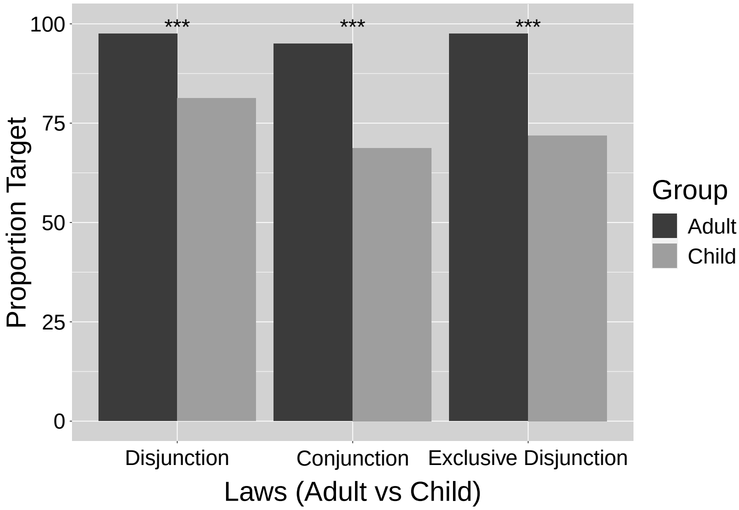


Figure 1: Proportion of target responses by group and scenario

Figure 2 presents another direct comparison between child and adult proportions of target answers, this time by condition. Adult responses were at ceiling for all conditions except for the Change & Disagree condition. In children's proportions of target responses, a marked contrast arises between the Maintain and Change conditions. Change conditions overall had lower proportions of target responses.

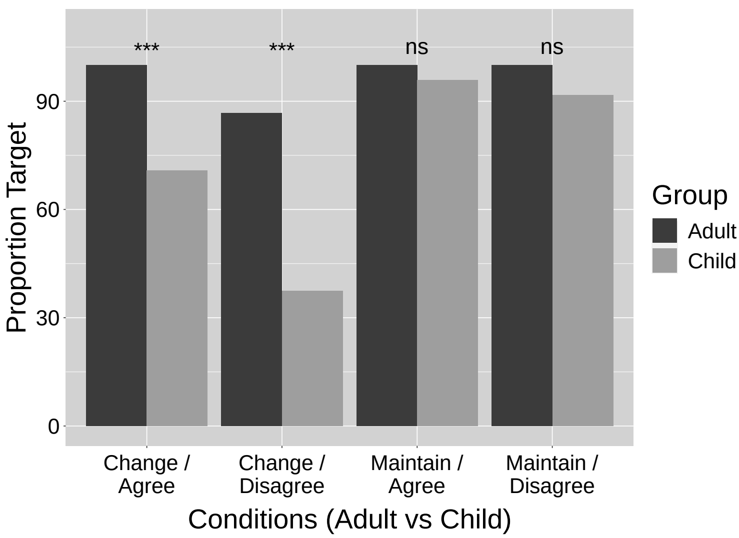


Figure 2: Proportion of child vs. adult target responses by condition

To test for differences between child and adult responses, as well as for effects due to scenario and condition, we fit the data to three binomial generalized mixed effects models, using the lme4 package in R (R Core Team, 2013).

The dependent variable is accuracy (expected adult-like response or not), and the factors are the law, the conditions, and in the case of our combined child and adult data model, the age group. The results are shown in Table 4.

Table 4: Results of mixed effects models (*$p < 0.05$, ***$p < 0.001$)

Factor	Estimate	SE	z-score	Pr(> |z|)
Adult and Child Model				
Intercept	4.7964	1.0119	4.740	2.14e-06 ***
Conj law	-0.2819	0.7529	-0.374	0.708064
Ex. Disj law	-0.4502	0.7529	-0.598	0.549923
Agree (vs. Disagree)	-2.5059	0.7552	-3.318	0.000906 ***
Maintain (vs. Change)	3.0397	0.8488	3.581	0.000342 ***
Child (vs. adult)	-2.8528	0.6885	-4.144	3.42e-05 ***
Adult Model				
Intercept	2.102e+01	3.414e+03	0.006	0.995
Conj law	-8.109e-01	1.318e+00	-0.615	0.538
Ex. Disj law	3.916e-16	1.491e+00	0.000	1.000
Agree (vs. Disagree)	-1.882e+01	3.414e+03	-0.006	0.996
Maintain (vs. Change)	1.883e+01	3.393e+03	0.006	0.996
Child Model				
Intercept	1.7478	0.5851	2.987	0.00282 **
Conj law	-1.2440	0.6124	-2.031	0.04222 *
Ex. Disj law	-0.9968	0.6204	-1.607	0.10810
Agree (vs. Disagree)	-1.0079	0.4904	-2.055	0.03986 *
Maintain (vs. Change)	2.1785	0.5552	3.924	8.72e-05 ***

Our first model considers both child and adult data. Through this model, we observe a main effect of age group. A second similar model was fitted only to the adult data. The results show no main effect of condition or Scenario ($p > .5$ in all cases) . Finally, a third model was fitted to only the children's data. There was evidence of a main effect due to Maintain (vs. change) and Agree (vs. disagree). In addition, a significant effect due to the conjunctive law was found ($p = 0.042$). These results indicate that for children, but not for adults, the conditions ended up having an effect on target responses to the counterfactual questions.

We next consider whether, when giving a non-target answer, children opt to change a fact within the system (e.g., they respond to the disjunctive Change & Agree condition by placing Penguin in the pool) or the law of the system (e.g., they respond to the disjunctive Change & Agree condition by placing Giraffe, but not Penguin or Crocodile in the pool). This was determined using predictions given by the corresponding causal network for the scenario). Table 5 shows that when children behaved in a non-target way, they largely preferred to change facts within the scenario.

Table 5: Proportion and count of children's non-target fact vs. law responses, given non-target response to counterfactual question

Conditions	Number of non-target responses	Proportions and counts of non-target facts and laws
Change & Agree	9	**Non-target Facts: 0.88 (7/8)** Non-target Laws: 0.13 (1/8) Other: 0.00 (0/7)
Maintain & Agree	2	Non-target Facts: 0.5 (1/2) Non-target Laws: 0.00 (0/2) **Other: 0.5 (1/2)**
Change & Disagree	13	**Non-target Facts: 0.85 (11/13)** Non-target Laws: 0.15 (2/13) Other: 0.00 (0/13)
Maintain & Disagree	4	**Non-target Facts: 1.00 (4/4)** Non-target Laws: 0.00 (0/4) Other: 0.00 (0/4)

In all conditions in which non-target responses were given (except for the Maintain & Agree condition, in which only one non-target response was recorded), children changed the non-antecedent fact in the scenario much more frequently than they changed the law of the scenario. To break down the results further, the only recorded non-target law responses were in the exclusive disjunctive scenario.

4. Discussion

Our results show that children produce significantly more non-target answers than adults. In addition, within children's responses, the condition has a significant effect on responses, while scenario type does not.

Taking a closer look at the responses by condition, we find that the Change conditions elicit more non-target responses than their counterparts, in which no facts were required to change. For example, in the disjunctive Change conditions, children appear to change the location of Penguin, in order to allow Giraffe to slide down. This may indicate that children are sensitive to the goal stated in the scenario. When facts are required to change in order to achieve Giraffe's goal, children are more willing to change the facts. When facts do not need to change to achieve Giraffe's goal, children do not change them, and give mostly adult-like responses. A similar pattern does not arise in the adult data, which additionally may indicate that adults are less sensitive to Giraffe's goal, and instead judge the given counterfactuals primarily through the similarity principle.

Whether the participant must agree or disagree with the counterfactual in order for Giraffe to achieve his goal also affects children's responses. Children give significantly fewer adult-like responses in the conditions in which the answer is required to be "no" in order for Giraffe to achieve his goal. In the Change & Disagree condition, this indicates that there is no yes-bias resulting in non-target answers. This is because the target answer in this condition is "yes", but a large proportion of child participants answered "no".

We now turn to the primary question at hand, and take a closer look at the Change & Agree condition. Of the seven non-target responses children gave in the Change & Agree condition, six involve a non-adult change to facts. For example, in the disjunctive scenario, children stated that Penguin would have gone down the slide. A similar pattern emerges in other conditions as well. Non-adult answers, in the great majority of cases, involve choosing a counterfactual scenario in which a non-antecedent fact is given up, and the law of the scenario is maintained.

Children generally remember and adhere to the law (e.g., in the disjunctive scenario, Giraffe needs at least one friend in the pool.). They therefore remain sensitive to the law when reasoning counterfactually. Facts (e.g., whether Penguin went in the pool or not in the actual world story set-up) are more malleable for children. They change facts in the actual world (unlike adults) in order to allow Giraffe to swim in the pool.

Why might children allow greater flexibility for facts? The answer to this is less clear. In earlier work on counterfactuals (e.g., Byrne, 1997) a relationship was found between working memory ability and counterfactual reasoning ability. It is therefore possible that children have greater difficulty maintaining the assignments (e.g., 1 or 0) of non-antecedent facts in alternative worlds, since that induces a greater cognitive load (i.e., having to remember not only the non-veridical assignment of the antecedent fact, but also the consequent fact - a third variable may just be too much for children to maintain). In this case, one would expect the transition from non-adult counterfactual reasoning to mature counterfactual reasoning to occur gradually, and be correlated strongly with performance on working memory tasks. We refer to this possibility as the *refinement over time* hypothesis. According to this hypothesis, immature counterfactual reasoning is not so different from mature counterfactual reasoning. Children inherently employ a similar strategy to adults, but they are less proficient at doing so, due to constraints on their processing ability. There is a clear continuity in development between child and adult reasoning, and child grammar is similar to that of adults.

Another possibility is that children are more liberal with the counterfactual worlds they allow. While adults may rule out worlds in which non-antecedent facts are needlessly altered, children may not. Reasoning over alternative possibilities, and being able to eliminate non-preferable alternatives are two distinct steps in counterfactual reasoning. While children may be successfully applying the first step, and be able to generate possible worlds, they may fall short of the second step, which involves application of the similarity principle.

In the case of the Change condition, children would have an incentive to use the world in which non-antecedent facts are altered, since those allow the goal (Giraffe sliding down) to be achieved. This possibility, which we refer to as the *maturational change in reasoning* hypothesis, corresponds to the following developmental pattern: When children reason about counterfactuals, they take into consideration a greater range of possibilities, and therefore do not employ the same strategy as adults, who pare down the number of counterfactual alternatives, as part of their reasoning process. As children's reasoning develops, they shift their strategy from the simpler "use any world" approach, to the "use only the closest worlds" approach. According to this hypothesis, there is not a clear continuity between child and adult reasoning, and children's grammar is dissimilar from that of adults.

In the current study, it also appears that children are not using the Basic Conditional Reasoning (BCR) strategy. In the disjunctive scenario, "Giraffe goes down the slide" has two possible causes: "Crocodile goes down the slide" and "Penguin goes down the slide". Children employing BCR might conclude that e.g., if Crocodile stays at the top, then the resulting event cannot occur, so Giraffe stays at the top as well. However, in the disjunctive Maintain & Disagree condition, children, at ceiling, did not follow this strategy when presented with a counterfactual such as "If Crocodile had decided to stay at the top, would Giraffe have decided to stay at the top?" Here, children reason that Giraffe would have gone down the slide. Responses to the Maintain & Disagree condition for the other two scenarios patterns similarly. We find that children keep track of other aspects of the scenario (e.g., Penguin's position), and use these aspects to justify their responses.

In a further study, it would be interesting to explore adult non-target answers in more challenging scenarios, and consider whether they show similar patterns to the child responses in the present study. This could help disambiguate between the proposed explanations for non-adult behaviors and learning pathways. Another further step one could pursue is to test a wider variety of scenarios. In the present study, we limit the scenarios to three variables and simple laws. However, it would be valuable to consider whether children's response patterns change with more difficult stimuli, and to compare their response patterns to those of adults.

5. Conclusion

When children give non-target answers to counterfactual questions, what is the nature of the changes they allow to the actual world? Adults take a parsimonous approach in their treatment of facts and laws of the actual world model, not changing them if they were not part of the antecedent, or causally dependent on the antecedent. We find that children are willing to change facts from the actual world, but maintain the laws of the scenario. They do this with greater frequency than adults, who gave target answers almost at ceiling. We have therefore shown that using causal models and the methodology developed here allows us to precisely identify how children differ from adults when reasoning counterfactually.

References

Beck, Sarah R. and Guthrie, Carlie. (2011). Almost thinking counterfactually: Children's understanding of close counterfactuals. *Child development*, 82(4):1189–1198.

Beck, Sarah R., Riggs, Kevin J., and Burns, Patrick. (2011). Multiple developments in counterfactual thinking. *Understanding counterfactuals, understanding causation*, pages 110–122.

Byrne, Ruth MJ. (1997). Cognitive processes in counterfactual thinking about what might have been. *The psychology of learning and motivation: Advances in research and theory*, 37:105–154.

Edgington, Dorothy. (2011). Causation first: Why causation is prior to counterfactuals. *Understanding counterfactuals, understanding causation: Issues in philosophy and psychology*, page 230.

Frosch, Caren A. and Byrne, Ruth MJ. (2012). Causal conditionals and counterfactuals. *Acta psychologica*, 141(1):54–66.

German, Tim P. and Nichols, Shaun. (2003). Children's counterfactual inferences about long and short causal chains. *Developmental Science*, 6(5):514–523.

Hiddleston, Eric. (2005). A causal theory of counterfactuals. *Noûs*, 39(4):632–657.

Kuczaj, Stan A. and Daly, Mary J. (1979). The development of hypothetical reference in the speech of young children. *Journal of Child Language*, 6(3):563–579.

Lewis, David. (1979). Counterfactual dependence and time's arrow. *Noûs*, 13(4):455–476.

McCormack, Teresa., Frosch, Caren., and Burns, Patrick. (2011). Children's causal and counterfactual judgements. *Understanding counterfactuals, understanding causation: Issues in philosophy and psychology*, page 54.

McCormack, Teresa., Ho, Margaret., Gribben, Charlene., O'Connor, Eimear., and Hoerl, Christoph. (2018). The development of counterfactual reasoning about doubly-determined events. *Cognitive Development*, 45:1–9.

Nyhout, Angela. and Ganea, Patricia A. (2019). Mature counterfactual reasoning in 4-and 5-year-olds. *Cognition*, 183:57–66.

Nyhout, Angela., Henke, Lena., and Ganea, Patricia A. (2019). Children's counterfactual reasoning about causally overdetermined events. *Child development*, 90(2):610–622.

Pearl, Judea. (2009). *Causality*. Cambridge University Press.

R Core Team (2013). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.

Rafetseder, Eva., Cristi-Vargas, Renate., and Perner, Josef. (2010). Counterfactual reasoning: Developing a sense of "nearest possible world". *Child development*, 81(1):376–389.

Rafetseder, Eva., Schwitalla, Maria., and Perner, Josef. (2013). Counterfactual reasoning: From childhood to adulthood. *Journal of experimental child psychology*, 114(3):389–404.

Riggs, Kevin J., Peterson, Donald M., Robinson, Elizabeth J., and Mitchell, Peter. (1998). Are errors in false belief tasks symptomatic of a broader difficulty with counterfactuality? *Cognitive Development*, 13(1):73–90.

Rips, Lance J. (2010). Two causal theories of counterfactual conditionals. *Cognitive science*, 34(2):175–221.

Proceedings of the 46th annual Boston University Conference on Language Development

edited by Ying Gong
and Felix Kpogo

Cascadilla Press Somerville, MA 2022

Copyright information

ISSN 1080-692X
ISBN 978-1-57473-077-7 (2 volume set, paperback)

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