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The development of counterfactual reasoning about doubly-determined events.

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The Development of Counterfactual Reasoning about Doubly-Determined Events

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Abstract

Previous studies of children's counterfactual reasoning have focused on scenarios in which a single causal event yielded an outcome. However, there are also cases in which an outcome would have occurred even in the absence of its actual cause, because of the presence of a further potential cause. In this study, 152 children aged 4-9 years reasoned counterfactually about such scenarios, in which there were 'doubly-determined' outcomes. The task involved dropping two metal discs down separate runways, each of which was sufficient to knock over a toy pig. One of the runways was shorter than the other, meaning that one of the discs actually knocked over the pig whereas the other always arrived too late to do so. Children were asked whether the pig would have been knocked over in the absence of the first metal disc descending the runway. We found that children could accurately answer such counterfactual questions by 6-7 years.

Keywords: Counterfactual reasoning; causal reasoning; cognitive development

The Development of Counterfactual Reasoning about Doubly-Determined Events

1. Introduction

Numerous studies have examined the development of counterfactual reasoning (e.g., Beck, Riggs, & Gorniak, 2009, 2010; German & Nichols, 2003; McCormack, Butterfill, Hoerl, & Burns, 2009; Perner, Sprung, & Steinkogler, 2004; Riggs, Peterson, Robinson, & Mitchell, 1998). In these studies, children were typically either shown or told about an event sequence and asked to judge what would have happened if an aspect of the world had been different. For example, Riggs et al. (1998) told children about a fireman, Peter, who is at home in bed because he does not feel very well, but then goes to the Post Office after getting a phone call asking him to go to help put out a fire there. In the counterfactual reasoning task, children had to judge where Peter would be if there had been no fire, with the correct answer being that he would be in bed. Children who are 4 to 5 years can typically answer these sorts of questions correctly. Children's ability to correctly answer such counterfactual questions has been shown to be related to other cognitive skills, in particular false belief understanding (Perner et al., 2004; Riggs et al., 1998) and aspects of executive functions (Beck et al., 2009; Drayton, Turley-Ames, & Guajardo, 2010).

All of the studies mentioned have examined what can be termed reasoning involving "real-world" counterfactuals: reasoning about alternatives to events as they happened at a particular past time (e.g., in Riggs's et al.'s study, what would have been the case if the Post Office fire had not occurred). Reasoning about real-world counterfactuals has been distinguished from reasoning about other types of non-actual scenarios, including hypothetical, pretend, or fictitious scenarios (Beck, 2016; Hoerl, McCormack & Beck, 2011). Whilst this latter type of reasoning, too involves considering scenarios that do not match reality, it does not require mentally undoing an aspect of an actual past event sequence that has happened. Theorists differ in terms of whether they think that the term counterfactual

reasoning should be extended to cover this type of reasoning as well (Beck, 2016; Hoerl et al., 2011; Perner & Rafetseder, 2011; Weisberg & Gopnik, 2013; Woodward, 2011). For example, Weisberg and Gopnik (2013; 2016) suggest that while it might be possible to distinguish between reasoning about real-world counterfactuals and reasoning about other non-actual scenarios, the latter is also a type of counterfactual thought that relies on the very same cognitive structures. Their motivation for this claim stems from the idea that both sorts of thought can be modelled within a Causal Bayes Net framework by assuming that they both involve an imaginary intervention on a variable in a graphical causal model to fix its value and then calculating the effects of this intervention (Weisberg & Gopnik, 2013; for a detailed description of such modelling, see Hagmayer, Sloman, Lagnado, & Waldmann, 2007). However, other developmental psychologists argue that the ability to reason using real-world counterfactuals is quite different from the ability to reason about pretend or hypothetical scenarios, and that the former is particularly significant for both theoretical and practical reasons (Beck, 2016; Beck et al., 2011; Perner & Rafetseder, 2011; Rafetseder & Perner, 2014).

From a practical perspective, real-world counterfactual reasoning is assumed to be important for a range of aspects of judgment, learning, and decision making, such as learning not to repeat one's mistakes as a result of experiencing regret, according responsibility for past actions, and making moral judgments (Byrne, 2016; Epstude & Reese, 2008). From a theoretical perspective, reasoning using real-world counterfactuals has been taken to be indicative of a distinctive type of cognitive skill. Specifically, it is assumed to involve (i) the ability to construct and hold in mind simultaneously two representations of the world (what actually happened, and the counterfactual scenario; Byrne, 2007, 2016) and (ii) an understanding of how these two representations are related to each other (Beck et al., 2011; Perner & Rafetseder, 2011). In holding both representations in mind and understanding the

relation between them, children are assumed to grasp that the counterfactual scenario involves a negation or undoing of a specific aspect of the actual sequence of events specified in the antecedent of the counterfactual (e.g., in the above example, there not having been a fire in the Post Office). Because children must consider them to be alternative representations of the very same past time, there is a sense in which there is a conflict between the two representations that does not exist in the case of entertaining representations of pretend or hypothetical scenarios (Beck, 2016; Beck et al., 2011).

This way of characterizing what is involved in reasoning using real-world counterfactuals has important implications. First, Beck, Robinson, Carroll, and Apperly (2006) suggest that grasping that there is “a common past that unites counterfactual and real worlds” (Beck, 2016, p. 254) is part of understanding a fundamental feature of the world, namely that at any given point in time multiple possible events could occur. Such a claim forges a close link between this type of counterfactual reasoning and an understanding of the nature of time itself (McCormack, 2015; McCormack & Hoerl, 2008). Second, this connection between the two representations places important constraints on the construction of the counterfactual alternative: the counterfactual alternative should mirror what actually happened in the real world, only differing in terms of the impact of negating the specific event mentioned in the antecedent. We can see how this principle might be put to work in the case of reasoning about Peter and the Post Office fire: it is judged that Peter would be in bed if the Post Office had not caught fire because it is assumed that all other things are equal in that counterfactual scenario (e.g., that Peter did not separately get phoned and asked to help put out a fire in the hospital). Following Lewis (1973a), Rafetseder, Schwitalla, and Perner (2013) refer to this as applying the Nearest Possible World Constraint.

1.1 When does real-world counterfactual reasoning develop?

If the distinction between real-world counterfactual reasoning and reasoning about other types of non-actual scenarios is a meaningful one, then it might be predicted that these two types of reasoning show different developmental trajectories. It is well-established that children are capable of reasoning about pretend and fictitious scenarios early in development, with 2-year-olds able to make certain types of judgments about pretend events (Harris, Kavanaugh, & Meredith, 1994; Harris & Kavanaugh, 1993). However, it is plausible that, because of its cognitive demands, real-world counterfactual reasoning does not emerge until later. The empirical challenge is to try to devise tasks that distinguish between this specific type of counterfactual reasoning and other types of reasoning. This challenge arises because of the possibility that children may give the correct answers in counterfactual reasoning tasks without actually engaging in real-world counterfactual reasoning (Beck et al., 2010; Beck et al., 2011; Rafetseder, Cristi-Vargas, & Perner, 2010; Rafetseder et al., 2013).

An example from a task used in Harris, German, and Mills' (1996) influential study of counterfactual reasoning can be used to illustrate this possibility. In Harris et al.'s study, children observed short sequences of events, such as a doll called Carol walking across the floor and leaving dirty footprints, because she was wearing muddy boots. The majority of 3-year-olds were able to answer such counterfactual questions as "What if Carol had taken her shoes off, would the floor be dirty?" On the face of it, it looks like children were engaging in real-world counterfactual reasoning, in which they mentally changed a specific aspect of the past event of Carol arriving home and walking across the floor, namely whether she kept her shoes on. However, Rafetseder et al. (2013; see also Rafetseder et al., 2010; Rafetseder & Perner, 2010) argued that children can answer these sorts of questions without thinking counterfactually at all. They suggested that instead such questions can be answered correctly using what they term basic conditional reasoning (BCR). BCR is assumed to involve reasoning using conditionals that apply to general states of affairs: e.g., "If someone takes

their shoes off, the floor stays clean.”; “If someone doesn’t get a phone call, they will stay in bed.”

The general states of affairs that such conditionals describe can sometimes differ from what has actually obtained: for example, children may, using BCR, correctly apply the principle “If someone takes their shoes off, the floor stays clean” to answer a question in circumstances in which a person did not actually take their shoes off and the floor is dirty. That does not mean, though, that under such circumstances children need to be engaging in real-world counterfactual reasoning in order to do so. The claim is that children can correctly answer questions that may be expressed as counterfactuals by applying only tenseless general if-then principles rather than actually mentally undoing what has happened in this specific instance.

The idea, then, is that there may be two ways to end up with the correct answer to the question “What if Carol had taken her shoes off, would the floor be dirty?” One is reasoning counterfactually along the lines of “If Carol had taken her shoes off, then she would not have left muddy footprints, so the floor would be clean now”. The other is to gloss the counterfactual question as one about what usually happens – “When Carol takes her shoes off, does the floor get dirty?” – and to answer only using the conditional “If someone takes their shoes off, the floor doesn’t get dirty.” Some of the tasks used with young children are particularly likely to be ones in which it is possible to rely on BCR, because they involve familiar circumstances about which children will possess knowledge in the form of these sorts of general if-then principles. How, then, can we tell if children are using real-world counterfactual reasoning or BCR, given that both of these types of reasoning will yield the same answers to counterfactual questions?

Rafetseder et al. (2013) point out that what is required is to identify circumstances in which these types of reasoning will yield different answers to counterfactual questions,

because aspects of the specific event in question mean that the conditional about general states of affairs does not apply in this particular instance. The example that Rafetseder et al. (2013) focus on to illustrate this is the case of what we will term ‘doubly-determined’ outcomes. Consider the case of two characters, Susi and Max, who both walk across a floor in dirty shoes. Would the floor be clean or dirty if Susi had taken off her shoes? The answer is that it would be dirty, because even if Susi had taken off her shoes, Max would still have left his muddy footprints. To get the correct answer to this question involves considering the specific events that unfolded in this particular case (i.e., that there were two children, both of whom made the floor dirty), and the effect of mentally undoing just Susi taking her shoes off. Simply relying on the conditional “If someone takes their shoes off, the floor stays clean”, and applying it to Susi’s case, would yield the incorrect answer to the counterfactual question.

Rafetseder et al. (2013) gave children, adolescents, and adults counterfactual reasoning tasks that either had this doubly-determined structure or concerned events that were singly-determined (e.g., only Susi walked across the floor and made it dirty). All age groups did very well on the singly-determined questions (5- to 6-year-olds were right 93% of the time, and the other age groups 100% of the time). However, there were remarkably low levels of performance on the tasks involving doubly-determined events: although adults and adolescents were at or close to ceiling, children as old as 9 were correct only 53% of the time, and 5- to 6-year-olds only 18% of the time. On the basis of these findings, Rafetseder et al. concluded that counterfactual reasoning abilities are not properly intact until early adolescence.

Rafetseder et al.’s results provide novel support for the idea that real-world counterfactual reasoning develops later than other sorts of thinking about non-actual scenarios, and we agree that examining counterfactual reasoning about doubly-determined

events addresses this issue. However, we question whether it is really the case that this sort of reasoning is not intact until as late as adolescence. There are a number of specific features of Rafetseder et al.'s (2013) task that may have contributed to the pattern of results that they obtained. The first concerns the demands of the doubly-determined task on memory and attentional resources. We suspect a key issue is whether children actually bring to mind the second character or event at all when answering the counterfactual question following doubly-determined stories. The control questions used in the task (e.g., "Was the floor clean or dirty before Susi walked in?") only focused on the character (or event) that was mentioned in the counterfactual, perhaps making it less likely that children would retrieve information about the secondary character (or event). Indeed, it was crucial in doubly-determined stories that children tried themselves to remember what had actually happened regarding the other character (or event) in the story, because there were no visually available cues at test that would allow them to deduce the causal consequences of that character's actions (or of the event). These considerations suggest that it might be possible to improve children's performance on counterfactuals regarding doubly-determined events by making this sort of information more apparent or available at test.

Second, Rafetseder et al. (2013) used stories involving mental rather than physical causation, in the form of people deciding to do things. While in itself this is not necessarily problematic, in the context of doubly-determined events it can create difficulties when it comes to interpreting the relevant counterfactuals. For instance, above we assumed that the correct answer to the question as to whether the floor would be clean or dirty if Susi had taken off her shoes is that it would be dirty, because Max would still have left dirty footprints. This is to assume that, in the counterfactual scenario, even though Susi had taken her shoes off, Max would have kept his on. The difficulty with this assumption is that children may be aware that people's decisions are often influenced by what they observe

others doing or what has already happened to them. Thus, they might instead assume in the counterfactual scenario that (e.g.) if Max saw Susi take her shoes off then he would take his off too. This would lead to their answers about doubly-determined scenarios being scored as incorrect.

Finally, we note that the causal sequences recruited in Rafetseder et al.'s (2013) task all involve familiar scenarios about which children would be likely to possess generalized if-then principles (e.g., if someone stays quiet the baby doesn't wake; if it doesn't rain, people don't get wet), and in such circumstances it might be particularly likely that children use BCR rather than appropriately reasoning counterfactually (Rafetseder & Perner, 2010). While it is of course common to use familiar scenarios in cognitive tasks used with young children to give them the best possible chance of demonstrating their cognitive skills, in this instance it may have been detrimental rather than beneficial to performance. It may be more suitable to use a task involving an unfamiliar scenario, in which such principles are less likely to come easily to mind, provided that children possess the necessary causal knowledge to reason appropriately about the causes and effects in the task.

1.2 The current task

In designing the current task, we bore in mind the issues raised above about Rafetseder et al.'s (2013) paradigm. We used a task that, although novel in structure to children, involved simple physical causal principles: there were two heavy metal discs (one with a picture of a red bird, and the other with a picture of a yellow bird) that rolled down one of two runways to knock over an object (a green pig) located in the centre between the runways. The runways were of different lengths, so that the disc with the red bird always arrived at the bottom before the disc with the yellow bird. Each of the runways could be blocked by inserting pegs into their centres, preventing the discs from descending all the way to the bottom. In all types

of trials, children saw the two discs released simultaneously at the tops of the runways. In doubly-determined trials, both discs rolled down the runways to the centre location where the pig was; in singly-determined trials, only one of the discs rolled down the runway all the way to the bottom, with the other stopping part-way down because its runway was blocked with a peg. Children were then asked counterfactual questions that, to answer correctly, involved undoing the descent of one of the metal discs.

There were two types of counterfactual scenarios, corresponding to two ways of mentally undoing the disc's descent. In the Subtractive condition (see Figure 2), children were asked "If I had not rolled the red bird that time would the pig have fallen down?" The correct answer in doubly-determined trials was "Yes", because the yellow bird would have knocked over the pig; in singly-determined trials it was "No". In the Additive condition, children were asked "If I had put a peg in here (*on the red side*) would the pig have fallen down?" Again, in doubly-determined trials, the correct answer was "Yes" whereas in singly-determined trials it was "No". This design draws on the distinction made by psychologists (Roese, Hur, & Pennington, 1999; Roese & Olson, 1993) between subtractive counterfactuals, which involve undoing something that has in fact occurred, and additive counterfactuals, which involve assuming that an additional event occurred over and above what actually happened. We were interested in whether children would find counterfactual reasoning easier for doubly-determined scenarios in one of these two conditions. Many studies of children's counterfactual reasoning have used subtractive counterfactuals, including that of Rafetseder et al. (2013). However, when asked to spontaneously produce counterfactual alternatives to events, children produce up to five times more additive than subtractive counterfactuals (Begeer, Terwogt, Lunenburg, & Stegge, 2009; Guajardo & Turley-Ames, 2004; Guajardo, Parker & Turley-Ames, 2009). Guajardo et al. (2009) argue that subtractive counterfactuals may place greater demands on working memory. If working

memory is a limitation children's performance in doubly-determined scenarios, then it is possible that they may do particularly badly on subtractive counterfactual questions.

Our aim in designing the task, thus, was to give children the best possible chance of demonstrating real-world counterfactual reasoning about doubly-determined events. The information that children needed in order to answer the counterfactual question was visually available to them at test. That is, they could see whether the yellow bird had made it to the bottom of the runway on any given trial or whether it was prevented from doing so because its runway was blocked. Furthermore, because both birds were dropped on every trial, we hoped that children would pay attention to what happened to both of them each time, rather than having to spontaneously bring to mind the fact that there had been a second possible cause only in doubly-determined trials. With regard to the issue of whether children would infer that undoing the causal event should also result in the other potential cause being undone, we believed that it was unlikely that children would think that, in the absence of one of the bird's rolling down its runway, the other birds would also not roll down the other runway. During the training phase they observed the experimenter dropping birds individually, and they also observed the runways being blocked individually, making it apparent that the events were independent. Finally, although the props used in the task were likely to be familiar to children (they were taken from the popular app, Angry Birds™), the causal structure of the events was novel, making it less likely that children would default to using general if-then principles.

2. Method

2.1 Participants

One hundred and fifty two children participated in the study. Four age groups were tested, corresponding to four school years: forty four 4- to 5-year-olds ($M = 63$ months, Range = 56-72 months, 20 females); forty six 6 to 7-year-olds ($M = 86$ months, Range = 74-

91 months; 24 females); forty three 7- to 8-year-olds ($M = 97$ months, Range = 92-101 months; 22 females); and nineteen 8- to 9-year-olds ($M = 108$ months; Range = 102-118 months; 8 females). Children were recruited either from a school local to the first author's university or via advertisement in local media. Children were tested individually in their schools or in the university's developmental laboratory.

2.2 Materials

A mechanical box was constructed for the study of dimensions 68 x 24 x 14 cm; see Figure 1. One side of the box was red and the other was yellow, and each side had a sloping runway that ran from the top of the box to its centre. The runway on the red side was a diagonal that led directly to the centre, whereas the runway on the yellow side had a zig-zag shape. The consequence of this difference in the shapes of the runways was that any object travelling down the red runway always reached the centre more quickly than any object travelling down the yellow runway. In the centre of the box was a green pig mounted on a tilting metal shelf; the shelf was constructed such that, if an object hit a trigger below it, it would tilt forward, resulting in the green pig being turned upside down. The shelf stayed tilted over until it was manually reset by the experimenter. There was a clear Perspex cover over a well beneath the shelf, into which the experimenter could reach to retrieve the objects that travelled down the runways and reset the shelf. The animal characters used with the apparatus were based on characters used in the popular computer game, Angry Birds™. Each coloured slope had a corresponding heavy metal disc featuring a picture of either a red bird or a yellow bird that could be released from the top of the slope. When either of the discs reached the centre and hit the trigger, the shelf with the green pig on it would tilt over. If both discs were released simultaneously, the red one would always reach the centre first and knock over the pig before the yellow one arrived. In these circumstances, when the yellow bird arrived, it would roll into the well beside the red bird that had already reached the centre and

would not have any effect on the green pig. Finally, there were two holes drilled into the box, one on either side at the mid-point of each runway. There was a red peg and a yellow peg that could be inserted into the holes; when a peg was inserted it blocked the runway on that side, preventing the corresponding bird from rolling down the slope.

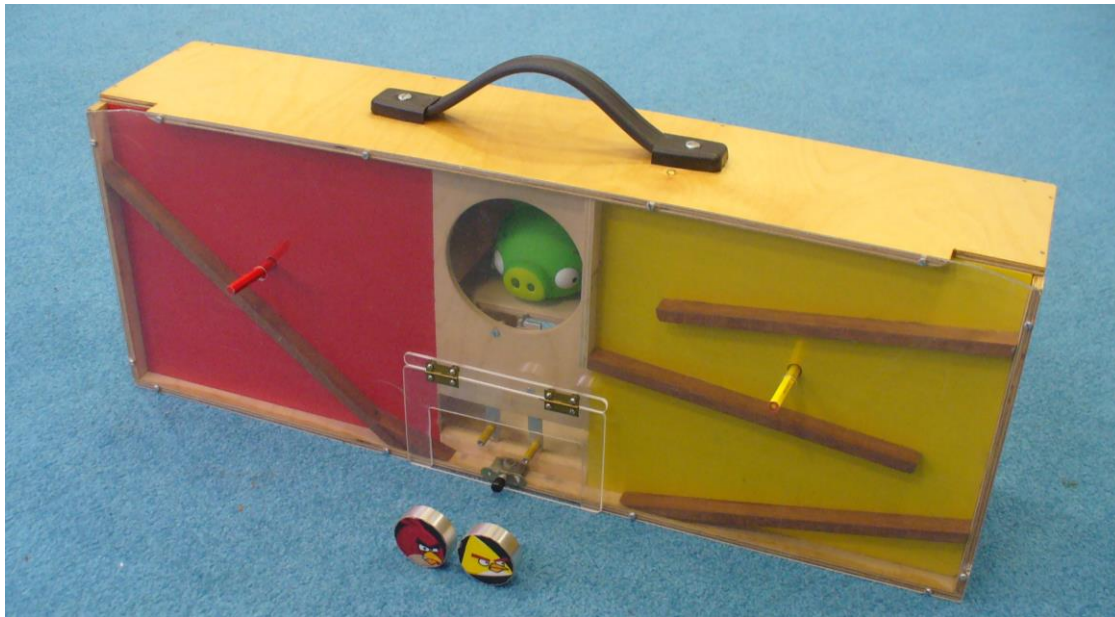


Figure 1. *Apparatus used in the task. The two metal discs with the pictures of the birds are shown at the bottom centre; the colored pegs used in the task to block the runways are shown inserted into the apparatus.*

2.3 Procedure

There was an initial familiarization phase during which children were shown how the box worked. The experimenter said “I’m going to roll the red bird and I want you to watch what happens.” She then released the metal disc with the red bird from the top of its runway; the disc rolled down and the green pig was knocked over. The experimenter then asked children “What happens when I roll down the red bird?”, and children were encouraged to answer. Children typically answered that the green pig was knocked down. The experimenter removed the red bird from the well below the shelf and reset the shelf with the pig on it. This

was repeated for the disc with the yellow bird and the other runway. The experimenter then told children that she was going to roll both birds down and asked them to watch. Both birds were dropped simultaneously, the red bird arrived first and knocked over the pig, and the yellow bird arrived subsequently. Children were then asked “What happens when I roll both birds?” The experimenter then introduced the peg for the red side, and inserted it into the hole on the red runway. She then asked children to watch while she rolled the red bird; the red bird rolled half-way down the runway and was then stopped by the red peg. Children were asked: “What happens when the peg is here (red side) and I roll the red bird?”; they typically answered that the green pig didn’t get knocked down, or that nothing happened. The experimenter then repeated this demonstration separately for the yellow peg on the yellow side. Finally, the experimenter inserted both pegs, and showed children what happened when both birds were dropped and both pegs were inserted. Children were asked “What happens when both pegs are in and I roll both birds?” Children of all ages had no difficulty answering the questions during this familiarization phase.

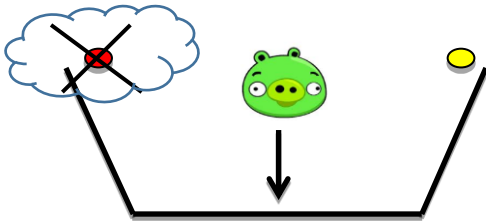
Children then completed four separate test trials, two in a Subtractive scenario and two in an Additive scenario. For each scenario, there were two types of trials: singly-determined and doubly-determined (see Figure 2 for details). At the start of each trial, the experimenter dropped the two birds down the runways simultaneously, and children watched what happened. Once the trial events had completed, children were asked the counterfactual test question for that trial.

In the Subtractive condition, at the start of the singly-determined trial, the experimenter said “I’m going to put the peg in here (on the yellow side).”, and placed the yellow peg in the yellow runway. She then said “I’m going to roll both birds down now, and I want you to watch what happens”. She dropped both birds, but only the red pig reached the well in the centre of the box because the yellow runway was blocked. Children were then

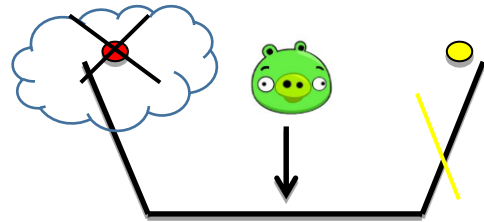
asked “If I had not rolled the red bird down that time, would the pig have fallen down?” The correct answer to the counterfactual question was “No”. The doubly-determined trial was similar except that the experimenter did not insert the yellow peg into the yellow runway. The correct answer to the test question was “Yes”, because if the red bird had not knocked the green pig over, the yellow bird would have knocked it over. In the Additive scenario, the singly-determined trial proceeded in exactly the same way as the singly-determined trial in the Subtractive scenario, but the test question was different. Children were asked “If I had put a peg in here (*on the red side*) as well would the pig have fallen down?” The correct answer was “No”, because both sides would have been blocked by pegs. The doubly-determined trial was also identical to that in the Subtractive scenario, except that children were asked “If I had put the peg in here (*on the red side*) that time would the pig have fallen down?” The correct answer was “Yes”, because the yellow bird would have knocked down the pig. All children completed the same four trials, with trials given to children in one of four different orders; children were randomly assigned to one of the orders.

Figure 2. *The two scenarios used in the study, along with the test questions and correct answers for each trial type. The thought bubble represents the counterfactual that children were asked to imagine, the red and yellow circles depict the metal discs that were dropped down the runways, and the red and yellow lines on either side depict the colored pegs that could be used to block the runways.*

Subtractive scenario: “If I had not rolled the red bird that time would the pig have fallen down?”

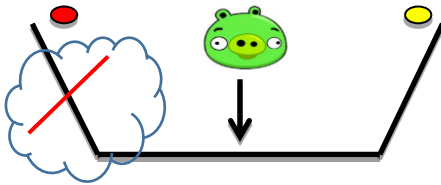


Doubly-determined: Correct answer is “Yes”

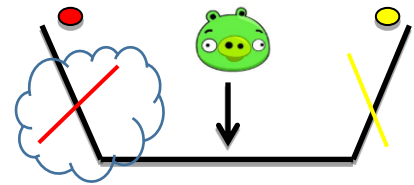


Singly-determined: Correct answer is “No”

Additive scenario: “If I had put a peg in here (on the red side) that time would the pig have fallen down?”



Doubly-determined: Correct answer is “Yes”



Singly-determined: Correct answer is “No”

3. Results

Figure 3 shows the percentage of times children answered each counterfactual question correctly, as a function of age and counterfactual scenario. A Kruskal-Wallis test on the total number of correct responses (0-4) showed that there was a significant effect of age, $H(3) = 30.53, p < .001$. Mann-Whitney U tests showed that the only significant differences between age groups on the total number of correct responses were between the 4- to 5-year-olds and each of the other three groups, $U = 565, p < .001, r = .40$ (medium effect size), for the comparison with 6- to 7-year-olds, $U = 493, p < .001, r = .44$ (medium effect size), for the comparison with 7- to 8-year-olds and $U = 126, p < .001, r = .58$ (large effect size) for the comparison with 8- to 9-year-olds. Separate analyses using Kruskal-Wallis tests showed that there was a significant effect of age on both singly-determined and doubly-determined trials, $H(3) = 11.01, p = .012$ and $H(3) = 22.45, p < .001$ respectively. A Wilcoxon test showed that performance was significantly better on singly-determined trials than doubly-determined trials, $Z = -4.51, p < .001, r = .26$ (small effect size). Although overall levels of performance were better in the Subtractive rather than the Additive condition, this difference did not reach significance, $Z = -1.89, p = .059, r = .08$. In summary, performance improved significantly after 4- to 5-years and was better on singly- than doubly-determined trials.

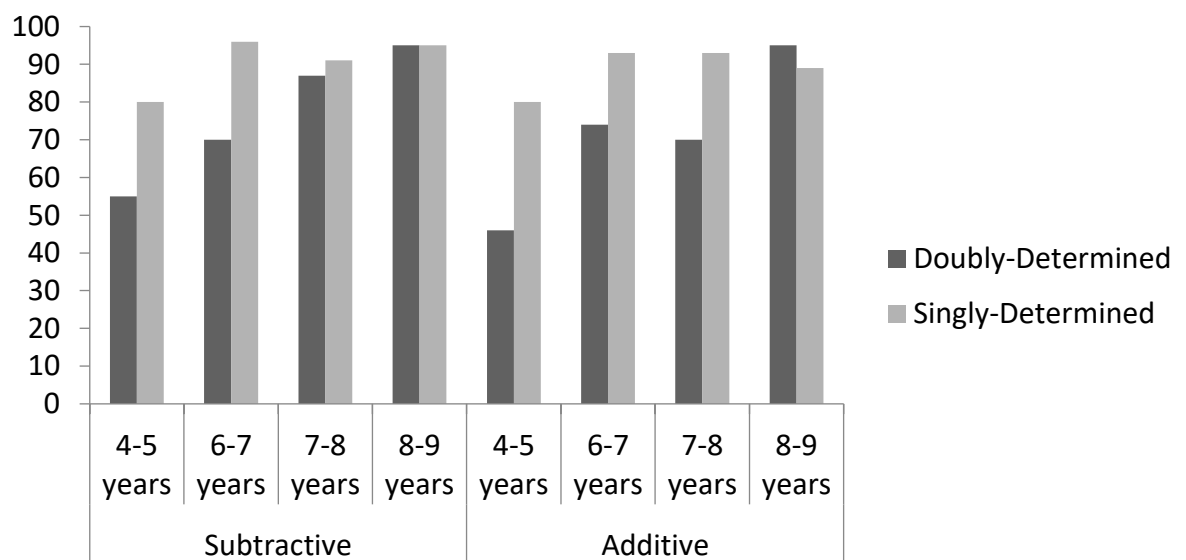


Figure 3. *The percentage of correct responses given to each trial type, as a function of age group and counterfactual scenario.*

In order to examine whether participants were relying on BCR, we compared whether responses differed between singly-determined trials and doubly-determined trials. For singly-determined trials, the correct answer to the counterfactual question is “No”, whereas for doubly-determined trials the correct answer to the counterfactual question is “Yes”; if participants were relying solely on BCR, their responses should not have differed between these trials. Figure 4 shows the percentage of “Yes” responses for each trial type, separately for the Subtractive and Additive conditions. It can be seen from the figure, that for all groups the percentage of “Yes” responses was higher for doubly- than singly-determined trials and that this was the case in both conditions. McNemar tests examined whether children gave significantly different numbers of “Yes” responses for singly- versus doubly-determined trials, separately for each age group and each type of counterfactual scenario. All comparisons were significant, all $ps < .01$. Thus, children’s responses differed depending on whether the outcome was doubly-determined or singly-determined.

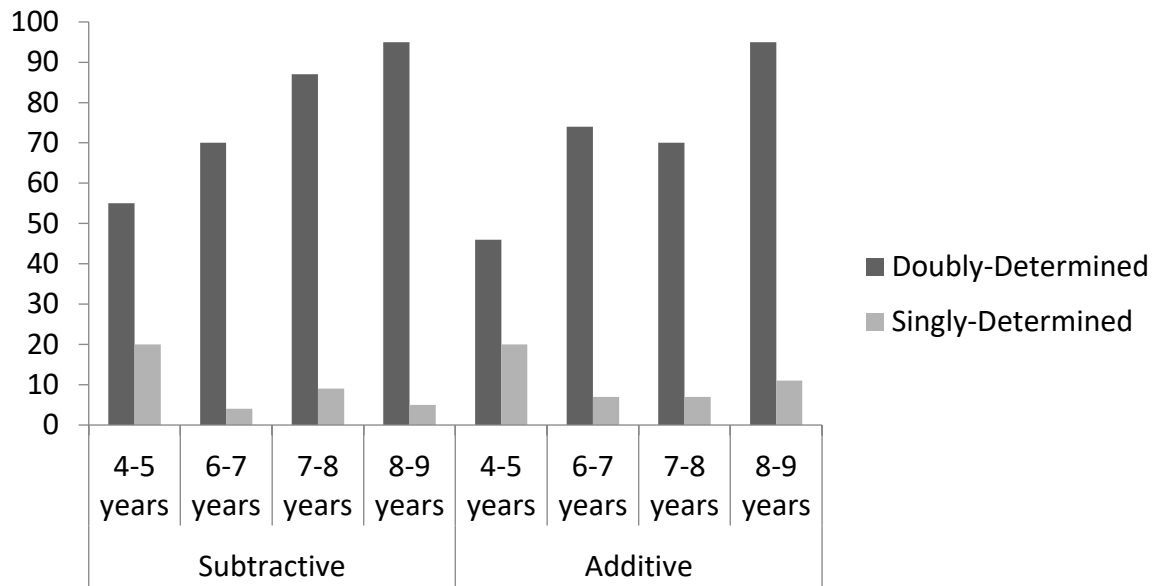


Figure 4. *The percentage of “Yes” responses given to each trial type, as a function of age group and counterfactual scenario.*

Our final analyses focused on whether children could be deemed to be performing at levels significantly above chance. Using binomial tests, we examined for each question type whether more children in each group gave the correct answer more often than would be expected by chance (assuming .5 chance level). For all groups and all question types, children gave more correct answers than would be expected by chance, all $ps < .02$, except for the 4- to 5-year-olds in the doubly-determined trials. The 4- to 5-year-olds did not perform above chance levels in either of the doubly-determined trials.

4. Discussion

The aim of our study was to examine when children are able to answer counterfactual questions about doubly-determined events, which we argued necessarily requires real-world counterfactual reasoning. We found that children were able to answer such counterfactual questions correctly by the age of 6-7 years, and were at ceiling in answering such questions by 8-9 years. However, 4- to 5-year-olds were unable to answer these questions correctly at a level above that expected by chance. Nevertheless, performance in this age group was

considerably better than in Rafetseder et al.'s (2013) study (which found levels of performance at 18% on counterfactual questions about doubly-determined events in this age group): children were correct around 50% of the time on these questions.

When asked the counterfactual question about whether the pig would have fallen over, the 4- to 5-year-olds answered “no” in doubly-determined trials significantly less often than in singly-determined trials, suggesting that their responses had a different basis across the trial types – if children were purely relying on BCR, they should have shown similar response patterns across the two trial types. However, because this age group did not perform above chance in the doubly-determined trials, it is not possible to be confident that counterfactual reasoning underpinned their performance on these trials. Nevertheless, our findings strongly suggest that children do not exclusively rely on BCR at least as early as 6-7 years. These findings are consistent with results from earlier studies that indicated that 6- to 7-year-olds can indeed reason counterfactually (Beck et al., 2006; Rafetseder & Perner, 2010). Moreover, they are also consistent with the growing body of research on the development of so-called counterfactual emotions (regret and relief) that indicates that children of this age have counterfactual thinking skills (O'Connor, McCormack, & Feeney, 2012, 2014; Weisberg & Beck, 2010, 2012). Real-world counterfactual reasoning is required for these emotions because they involve evaluatively comparing the actual outcome that resulted from a particular past decision with the counterfactual outcome that would have obtained had a different decision been made (Beck, 2016; Beck et al., 2011). Previous studies suggest that, by 6 to 7 years, children can experience regret, and this experience has an effect on the quality of their decision making (O'Connor et al., 2014). Taken together with these findings from previous research, our results strengthen the claim that real-world counterfactual reasoning is an ability possessed by children of this age, and are not consistent

with Rafetseder et al.'s (2013) suggestion that it is not until late childhood or adolescence that children can reason in this way.

We finish by considering why it is particularly interesting to demonstrate that children are capable of counterfactual reasoning about doubly-determined events. One reason was already mentioned in the Introduction. As Rafetseder et al. (2013) point out, children who reason correctly about these sorts of events are applying the Nearest Possible World Constraint in their reasoning: they are mentally undoing only the event that is negated in the antecedent of the counterfactual. It is difficult to interpret the findings of other types of studies of counterfactual reasoning as demonstrations of the ability to apply this constraint, whereas the findings of the current study indicate that by at least 6-7 years children do apply such a constraint. A further reason, though, for examining counterfactual reasoning about doubly-determined events is that these sorts of scenarios have long attracted extensive interest amongst philosophers interested in the relation between counterfactual and causal reasoning (Hall, 2004; Lewis, 1973b, 2004; Paul & Hall, 2013). In particular, these scenarios (typically referred to as cases of pre-emption in the philosophical literature) have been of interest because they constitute challenges to attempts to give an account of causation in terms of counterfactuals. Put simply, the idea behind a counterfactual account of causation is that what it is to say that A causes B is to say that in the absence of A, B would not occur. In the case of doubly-determined events, this does not straightforwardly hold – the red bird was the cause of the pig being knocked over, but even in the absence of the red bird, the pig would still have been knocked over. Theorists defending a counterfactual theory of causation must explain how the theory can deal with such cases.

The counterfactual theory of causation is a metaphysical theory about the nature of causation in the world, not a psychological theory. Nevertheless, it has sparked interest in considering what the psychological relation is between counterfactual and causal cognition

(Harris et al., 1996; Hoerl et al., 2011; Mandel, 2003; Spellman & Mandel, 1999; Woodward, 2011). For example, drawing on counterfactual theories of causation in philosophy, Harris et al. (1996) suggest that even very young children may use counterfactual reasoning in order to reach causal conclusions. That is, in attempting to identify what caused an event, they consider whether the event would have occurred without a putative cause and reason accordingly. Indeed, Harris et al. speculate that it is possible that this may be the fundamental way in which causal inferences are drawn even in infancy. Our current findings do not resolve the issue of the extent to which, developmentally, children's causal reasoning is underpinned by counterfactual thought (although the late emergence of real-world counterfactual thought places limitations on what sort of counterfactuals could plausibly be claimed to underpin preschoolers' causal judgments). However, our results do suggest that children's counterfactual judgments are distinct and separable from their causal judgments. In all of the test trials, the red bird caused the pig to fall over, so there was never any ambiguity over what was the causal event. Nevertheless, in doubly-determined trials the 6- to 7-year-olds did not judge that the pig would have failed to fall over in the absence of the event that they knew to have caused it to fall over. As with adults, children's causal and counterfactual judgments come apart under certain conditions (Mandel, 2003; Mandel & Lehman, 1996).

To conclude, we found good evidence to suggest that at least by the time they are 6-7 years old, children can answer counterfactual questions about doubly-determined events correctly. We agree with Rafetseder et al. (2013) that the ability to answer such questions is indicative of important achievements in the development of counterfactual cognition. Children could not answer such questions correctly if they were relying solely on BCR; nor could they do so if they failed to correctly apply the Nearest Possible World Constraint. Our findings suggest that children have mastered important aspects of counterfactual reasoning by the time they are at least 6-7 years. This does not mean that the accuracy of their

counterfactual reasoning will always match that of older children or adults. Children were not at ceiling on our task until 8-9 years, and we anticipate that in sufficiently complex scenarios that require holding in mind a number of pieces of information even these older children would be less accurate than adolescents or adults. Nevertheless, our findings suggest that 6-7-year-olds' counterfactual reasoning does not differ qualitatively in important ways from that of mature reasoners.

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