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Children's use of counterfactual thinking in causal reasoning

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Abstract

Research on children's causal thinking has emphasized the perception of temporal and spatial contiguity between cause and effect. However, our causal judgements often involve a contrast between a perceived sequence (A, then B) and a counterfactual case (in the absence of A, then not B) . In three experiments, children's capacity for such counterfactual thinking was assessed. In Experiment 1, children aged 3–5 years observed a sequence such as A causing B. Subsequently, they replied quite accurately to a question about a counterfactual sequence, for example: "What if A had not occurred, then B or not B?". In Experiment 2, children were asked about two counterfactual antecedents, one that would not have caused B, and one that (like the actual antecedent) would also have caused B. Children differentiated between the two types of antecedent. Finally, in Experiment 3, children heard stories in which the protagonist chose a course of action that led to a minor mishap (e.g., drawing with a black pen and getting inky fingers), having rejected an option that would have prevented it in experimental stories (e.g., using a pencil) or an option that would have led to an equivalent outcome in control stories (e.g., using a blue pen). Children aged 3 and 4 years often cited the failure to adopt another course of action as the cause of the mishap and, particularly in experimental stories, they focused on the rejection of the alternative option. Children's use of counterfactual thinking is discussed in relation to contemporary accounts of causal reasoning.

1. Introduction

According to Hume's well-known analysis of our everyday conception of a causal connection (Hume, 1739/1978), we observe no more than a regular

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succession of events, such as A, then B, but by virtue of an increasingly strong association in our mind between A and B, we come to infer a necessary causal connection between them. Hume's primary sceptical purpose was to show that the causal connection that we infer is, strictly speaking, not warranted by our empirical observation no matter how often it is repeated. In pursuing that sceptical goal, however, he also provided a persuasive analysis of our everyday, causal thinking.

Despite the influence of Hume's account, modern philosophical analysis has suggested that his characterization of our everyday causal thinking is only partially correct (Sosa and Tooley, 1993). A particularly interesting elaboration is provided by Mackie (1974). He claims that our notions of causality are often based not only on repeated observation of regularity but also on a judgement about the contrast between what is observed and what might have been observed instead. What we describe as a cause is an antecedent condition that we judge to make a difference in relation to a fixed set of circumstances. Given the antecedent condition the effect is produced but if the antecedent condition had not occurred in those circumstances neither would the effect. For example, in assessing why a lighted match has extinguished, we may conclude that it would have continued to burn had there not been a gust of wind from an open window, or alternatively, that it would have continued to burn had the match not been damp. In either case, our causal diagnosis includes a counterfactual judgement: an acknowledgement that the effect would not have occurred in the absence of the alleged cause. As Mackie acknowledges, our conception of causality includes other features. We assume an asymmetry between cause and effect, and some kind of causal mechanism. However, his analysis of our everyday conception of causality ascribes central importance to counterfactual thinking.

Such thinking could enter into causal analyses in two different ways. One possibility is that we first arrive at a causal conclusion and subsequently use that conclusion to draw a counterfactual inference. For example, pursuing the above example, if we conclude that the match has been blown out by a gust of wind we might subsequently draw the counterfactual inference that it would still be burning if the window had been closed. If we conclude that the match went out because it was damp, we might subsequently draw the inference that it would still be burning had it been allowed to dry. In either case, the causal conclusion precedes and guides later counterfactual thinking. A second possibility is that counterfactual considerations are brought to mind first and provide a basis for picking out a likely causal agent. Thus, someone who sees a match extinguished might first consider what would have happened had there been no gust of wind and having judged that the match would have remained alight, conclude that the wind blew it out.

Of these two potential roles for counterfactual thinking, Mackie emphasizes the second: the part played by counterfactual thinking in picking out a causal agent. Effectively, he claims that we do not reach a causal conclusion from merely observing successive events, rather we carry out a thought experiment in which we imagine what would have happened in the particular circumstances had a given antecedent condition not obtained. By comparing the outcome of such alternative

cases with the observed case, we can identify an alternative case where the observed outcome did not occur, and thereby identify the likely causal antecedent. This does not mean that he saw no role for counterfactual inferences following a causal conclusion but simply that he stressed the importance of counterfactual thinking in picking out a causal agent.

An important advantage of Mackie's analysis as compared to Hume's is that it explains why we focus on different causal agents for the same event, or event type, depending on how we perceive the circumstances that surround that event. Our causal conclusions vary depending on the type of alternative case that we bring to mind given that surrounding context. This can be illustrated with an example from Hart and Honoré (1959/1985) (p.35). When a fire breaks out in a factory, we might identify the cause as the dropping of a lighted cigarette. We would not typically regard the presence of oxygen as a cause even if we know that it is a necessary standing condition for a fire to occur. However, if a fire breaks out in a laboratory where special precautions are usually taken to exclude oxygen during experimental work, then we might attribute the fire to the (unexpected) presence of oxygen. The fact that we reach different conclusions about the cause of the fire in these two situations can be explained by Mackie's assumption that we mentally compare the observed case with alternative cases, and identify as the cause a condition that brings about a difference between the compared cases. With respect to the factory fire, both the observed case and any alternative case that we are likely to bring to mind will include oxygen. Accordingly, oxygen will not emerge as a condition that brings about any difference between the compared cases. With respect to the laboratory fire, however, the observed case will include oxygen but most alternative cases will not (insofar as they are likely to be based on routine conditions in the laboratory), so that the presence of oxygen will be perceived as a condition that brings about a difference.

Recent experimental research with adults has yielded support for this aspect of Mackie's analysis. Adults reach different causal conclusions about the same event depending on the alternative cases that they are prompted to bring to mind (Miller et al., 1990; Wells and Gavinski, 1989). In addition, Cheng and Novick (1991) have shown how adults' judgement about what constitutes the cause of an event, as opposed to a standing condition that merely enables an event, can be explained in terms of the particular alternatives that are invoked.

The study of causal thinking in infants and young children has been dominated by Hume's account. In particular, children's sensitivity to temporal and spatial contiguity between cause and effect has been an important focus (Bullock et al., 1982). Even investigators who have worked outside the empiricist tradition by looking for an early, and potentially innate, competence have emphasized the infant's perceptual sensitivity to the temporal and spatial contiguity between antecedent and consequent (Leslie and Keeble, 1987; Millar, 1972; Millar and Schaffer, 1972; Oakes and Cohen, 1990). Yet if Mackie's argument is correct, we would expect causal thinking involving a contrast case to emerge at some point in development.

At first sight, this type of causal thinking might appear to be a relatively

complex, and late-emerging capacity. In particular, it seems unlikely that infants or young children would bring a counterfactual case to mind, compare it to an observed case, and thereby identify a likely causal agent. However, Mackie makes a helpful distinction between a sophisticated and a primitive way of making such comparisons. In the sophisticated procedure, we invoke general propositions, based on induction, about what would follow under a contrary-to-fact supposition and we deduce certain consequences about the causal agent. The primitive procedure, by contrast, rests on a combination of imagination and analogy. Mackie illustrates this by reference to a causal episode whose general form is widespread, the "before and after" sequence. In an otherwise stable environment, we observe that a striking change X occurs (e.g., there is a sudden gust of wind); this change is followed by another change, Y (e.g., a lighted match goes out). By considering the stable period before X occurred, we can easily retrieve cases in which X did not occur, and Y likewise did not occur. We may then construct a case that contrasts with the observed sequence and use it to reach a causal judgement. Mackie puts it as follows: "... in a quite primitive and unsophisticated way we can transfer the non-occurrence of Y from the before situation to a *supposed* later situation, in which, similarly, X did not occur, and form the thought which is expressed by the statement 'If X had not occurred, Y would not have occurred'" (Mackie, 1974, p. 56). More generally, Mackie suggests that the imagination can supply a pertinent contrast case, whether it is borrowed from a recollection of the immediately preceding situation or from other situations, similar to the observed situation, save for the absence of X. This analysis highlights the way in which his psychological thesis both departs from and parallels that of Hume. Unlike Hume, Mackie assigns a key role to the contrast case rather than the observed repetition of like cases. Nonetheless, like Hume, he does not confine his analysis to the causal thinking of sophisticated adults. Mackie explicitly suggests that the primitive strategy might be available to very young children and animals: "... although we express this kind of thinking in words, its development need not have waited for the development of language. It is not essentially tied to verbal expression, and there is some reason to suppose that other, non-verbal animals share this capacity with us" (Mackie, 1974, p. 55)

Granted this conceptual argument, is there empirical evidence that young children can engage in counterfactual thinking? Various theorists have suggested that counterfactual thinking is a capacity that is unnatural or fragile even among adults if they lack access to various linguistic or cultural forms (Bloom, 1981; Scribner, 1977) but recent research offers more grounds for optimism. First, although children rarely produce fully formed counterfactual, conditional statements before the age of 4–5 years (Kuczaj and Daly, 1979; Reilly, 1983; Reilly, 1986), there is persuasive evidence that 2- and 3-year-olds can conceptualize what has not actually happened but might have happened, had circumstances been different. One simple and clear indication is the early production of "nearly" or "almost" which children use to call attention to events that come close to yielding a different outcome from the one observed (Kahneman and Varey, 1990). Bowerman (1986), Au (1992) and Harris et al. (1996) report appropriate

comprehension and production of "almost" from around 2 years of age. For example, C (aged 22 months) set down a pitcher on the edge of a sandbox; M caught it as it was about to fall; C remarked: "Almost fall" (Bowerman, 1986). Second, young school children perform quite accurately on counterfactual reasoning problems provided the content is familiar (Liu, 1985; Experiment 2). Indeed, even preschool children can draw accurate conclusions from a premise that runs counter to their everyday experience if they are prompted to regard the premise as merely suppositional (Au, 1992; Dias and Harris, 1988; Dias and Harris, 1990).

In sum, on both conceptual and empirical grounds it is worth exploring the possibility that young children can engage in counterfactual thinking and use that capacity in reaching causal conclusions. Three experiments were conducted with this possibility in mind. In the first experiment, children were asked to consider what would have happened had some critical element in the unfolding narrative sequence been different. Essentially, they were presented with a contrast case and asked to judge its likely outcome. In the second experiment, children were asked to judge the likely outcome of two different counterfactual possibilities: one in which the observed outcome would have been prevented, and one in which it would have occurred anyway. Finally, in the third experiment children were asked to provide causal explanations for an outcome. They were presented with narratives that described a given course of action and included a contrast with an alternative course of action that either would or would not have prevented the mishap that ensued. Taken together, the experiments were designed to show that when children are asked to explain an event, they can consider alternative counterfactual cases and reach different conclusions depending on the way in which those alternatives do or do not diverge from the actual case.

In Experiment 1, children were tested on four episodes. Each episode was presented in three parts. First, a simple causal sequence was enacted with the help of props. For example, a clean white surface (designated as a "floor") was dirtied by a doll who was made to walk across it with dirty shoes that left visible foot-prints. Next, children's appreciation of the transformation was checked: they were questioned about the state of affairs both before and after the transformation. Thus, pursuing the above example, they were asked whether the floor was now dirty, and also whether it was dirty before the doll's arrival. Finally, children were posed the critical test question. They were asked to imagine a departure from the sequence that they had witnessed, and to predict its outcome. For example, they were asked what would have happened to the floor had the doll removed her shoes before entering. A correct answer to this question required children to entertain a contrary-to-fact condition (since the doll had not, in fact, removed her shoes) and to imagine the causal outcome. This type of conditional thinking (i.e., the consideration of an antecedent condition that would not have led to the observed outcome) is what Mackie regards as an essential component of our everyday causal thinking.

EXPERIMENT 1

2. Method

2.1. Subjects

The subjects were 26 children aged 3–5 years, equally divided into a younger group (7 boys; 6 girls) ranging from 37 to 48 months (mean = 3 years 6 months), and an older group (7 boys; 6 girls) ranging from 52 to 62 months (mean = 4 years 10 months). Children were tested in a variety of preschools and nursery schools in Oxford, UK, serving a broad range of socio-economic backgrounds.

2.2. Procedure

Children were interviewed in a quiet corner of their classroom or play area. Each child was tested on four episodes. For each episode, children watched while a causal sequence was acted out in front of them with the help of props. For example, they were told:

> One day, the floor is nice and clean (experimenter points to a square of white plastic). But guess what? Carol comes home and she doesn't take her shoes off. (A doll was brought to the edge of the surface). She comes inside and makes the floor all dirty with her shoes. (The doll was walked across the floor, leaving dirty footprints).

Children were then asked two control questions. The *Now* Control Question was about the final situation, and the *Before* Control Question was about the initial situation. For example, "Is the floor dirty now?" and "Was the floor dirty before?"

Finally, children were asked the test question, in which they were required to imagine a contrary-to-fact condition, and to predict its impact, for example: "What if Carol had taken her shoes off – would the floor be dirty?"

The other three episodes together with their accompanying control and test questions are given in Appendix A. Several features of the various episodes should be underlined. First, two episodes called for yes/no replies (Episode 1 above and Episode 2 in Appendix A) whereas Episodes 3 and 4 called for a selective pointing response. Second, for the two episodes requiring yes/no replies, the final state (i.e., "dirty") was mentioned in all three questions for Episode 1, and the initial state (i.e., "standing up") was mentioned in all three questions for Episode 2. Accordingly, correct answers were: yes, no, no, for Episode 1 but no, yes, yes, for Episode 2. Thus, systematically correct responding could be distinguished from a "yes" or "no" bias. Finally, two of the test questions (Episodes 1 and 4) were formulated in the positive ("What if ...?") whereas two (Episodes 2 and 3) were formulated in the negative ("What if ... not ...?").

Table 1
Mean number of correct replies as a function of Age and Question (*SD* in parentheses)

	Question		
	Now	Before	Test
Younger	4.00 (0.0)	3.69 (0.6)	3.00 (1.1)
Older	4.00 (0.0)	4.00 (0.0)	3.46 (0.7)

The order of the four episodes was randomized across children.

3. Results

Children were scored for the number of episodes (out of four) for which they gave correct replies to the *Now*, *Before*, and *Test* questions. On three occasions, three different children (one younger and two older) first gave an incorrect reply that they then spontaneously revised. These three self-corrections (one in response to a control question, two in response to a test question) were accepted. Mean scores are given in Table 1 as a function of Age and Question.

Inspection of Table 1 shows that children in both age groups were very accurate in answering the two control questions but less accurate in answering the test questions. Sign tests confirmed that the *Now* questions were answered more accurately than the *Test* questions ($p < .008$ for younger children; $p < .031$ for older children. Similarly, the *Before* questions were answered more accurately than the *Test* questions ($p < .016$ for younger children; $p < .031$ for older children).

Despite their greater difficulty in answering the test questions, children were nonetheless quite accurate in absolute terms. Table 2 shows the number of children in each age group who were correct on 0, 1, 2, 3 or 4 test questions. The majority of children in the younger group (69%) and in the older group (85%) were correct on either 3 or 4 test questions. Two separate Kolmogorov–Smirnov tests confirmed that the distribution of scores differed from chance for both the younger group ($D(N = 13) = 0.400$, $p < .05$) and the older group ($D(N = 13) = 0.534$, $p < .01$). A similar result was obtained when the two age groups were combined ($D(N = 26) = 0.476$, $p < .01$).

Table 2
Mean number of children giving 0, 1, 2, 3 or 4 correct replies to 4 test questions as a function of Age

	Number of correct replies					
	0	1	2	3	4	*N*
Younger	0	2	2	3	6	13
Older	0	0	2	3	8	13

4. Discussion

Children were very accurate in describing both the initial and the final situation for each episode. They were less accurate in predicting the causal impact of the contrary-to-fact condition, as required by the test questions. Nevertheless, the majority of children made no errors or made a single error on the test questions. Their success suggests that even 3-year-olds can make counterfactual predictions.

Mackie's analysis of everyday causal thinking suggests that adults are alert to the way that certain departures from the observed antecedent conditions have or have not been associated with the elimination of the observed outcome. For example, returning to the example of the extinguished match, an observer might remember that shielding other matches of the same type from the wind did not stop them from going out. Thus, consideration of alternative antecedent conditions can help to exclude a potential cause of the outcome (e.g., a wind coming through an open window) while leaving others in play (e.g., the dampness of the match). In Experiment 1, children were questioned only about departures from the antecedent conditions that would have eliminated the observed outcome. In Experiment 2, we asked whether children were sensitive to the distinction between departures that would or would not eliminate the observed outcome.

Earlier findings summarized by Bullock et al. (1982) suggest that preschool children can make this distinction. Preschoolers watched a causal sequence: a rod was pushed forward through a post, and knocked down the first of five standing wooden blocks; the remaining blocks then proceeded to fall in a domino-like fashion; finally, the fifth block fell on a lever that tipped a toy rabbit off a platform. In one study, 3- and 4-year-olds were subsequently shown a variety of changes to the props making up the causal sequence and asked to predict whether such changes would or would not disrupt the causal sequence (Baillargeon et al., 1981). For example, they were shown a pliable rod or a differently coloured rod and asked to predict whether or not the rabbit would eventually be tipped off if the rod were pushed forward as before. Both 3- and 4-year-olds adjusted their predictions appropriately. They realized that certain alterations, such as making the rod pliable would disrupt the causal sequence whereas other alterations, such as altering the colour of the rod would result in the same causal sequence.

Experiment 2 paralleled this procedure. Children watched a causal sequence acted out, and they were then asked to predict the outcome following alterations that would or would not disrupt the causal sequence. However, two changes were introduced. First, children were not shown any alteration in the component props of the causal sequence. Instead, they were asked to imagine such an alteration. Second, the questions were posed in terms of the past rather than the future. Thus, children were asked to specify what would have happened, had the antecedent conditions been different.

Given the relatively good performance of 3-year-olds in Experiment 1, only 3-year-olds were tested in Experiment 2.

EXPERIMENT 2

5. Method

5.1. Subjects

The subjects were 26 children (14 boys; 12 girls) ranging from 37 to 48 months (mean = 3 years 7 months). Children were tested in two preschools schools in Oxford, UK, serving a broad range of socio-economic backgrounds.

5.2. Procedure

As in Experiment 1, children were interviewed in a quiet corner of their classroom or play area. Each child was tested on four episodes. For each episode, children watched while a causal sequence was acted out in front of them with the help of props. For example, they were told:

> One day the floor was nice and clean like this [Experimenter points to a square of white plastic]. But guess what? Naughty Teddy comes along and paints the floor like this [Experimenter makes Teddy, a hand puppet, paint the floor red].

Children were then asked two control questions and two test questions; each question focused on the issue of when and under what conditions the initial state (e.g., clean in the above example) would be maintained. The *Before* Control Question concerned the nature of this initial state (e.g., "Was the floor clean before?"; correct answer = yes). The *Now* Control Question concerned the current situation, and specifically whether the initial state now obtained (e.g., "Is the floor clean now?"; correct answer = no). Children were then asked two test questions, in which they were required to imagine each of two contrary-to-fact conditions, and to say whether the initial state would be preserved or changed. The *Preserve* test question posited an antecedent condition that would preserve the initial state (i.e., clean) (e.g., "If Teddy hadn't painted the floor with his brush, would the floor be clean now?"; correct answer = yes). The *Change* test question posited an antecedent condition that would (like the actual antecedent condition) change the initial state into the final state (i.e., dirty) (e.g., "If Teddy had painted the floor with his fingers instead, would the floor be clean now?"; correct answer = no).

The order of the two control questions was randomly varied across subjects, but the order of the two test questions was held constant because the reverse order was pragmatically awkward. Accordingly, correct replies for children who received the *Now* question, followed by the *Before* question and then two test questions were, respectively: no, yes, yes, and no. Correct replies for children who received the *Before* question followed by the *Now* question, and then the two test questions were, respectively: yes, no, yes, and no.

The other three episodes had a similar format. They involved a dry plate that Teddy wetted with water, a tower of bricks that Teddy knocked down with a stick, and a ball of Playdoh that Teddy squashed with his hand.

6. Results

In answering the two control questions, children were more likely to affirm the initial state (e.g., clean) for the *Before* question (mean = 2.81, $SD = 1.4$), than for the *Now* question (mean = 0.58, $SD = 0.9$). In answering the two test questions, children distinguished between the antecedent condition that would have preserved the initial state (*Preserve* test question) and the antecedent condition that would (like the actual antecedent) have changed it to the final outcome (*Change* test question). Thus, they were likely to affirm that the initial state would still obtain when they answered the *Preserve* (mean = 2.85, $SD = 1.3$) as compared with the *Change* test question (mean = 1.19, $SD = 1.1$).

To check these two conclusions, two separate t tests were carried out: one for the control pair of questions and one for the test pair of questions. These tests confirmed that children produced more affirmative replies for the *Before* than the *Now* control question ($t(25) = 7.306$, $p < .001$) and for the *Preserve* than the *Change* test question ($t(25) = 5.971$, $p < .001$).

7. Discussion

Experiment 2 confirmed the earlier findings of Baillargeon et al. (1981): 3-year-olds are quite accurate in distinguishing between an alteration to the antecedent conditions that would block the observed outcome as compared with an alteration that would yield the same outcome. Experiment 2 showed, in addition, that 3-year-olds can make such differential judgements when they are asked counterfactual questions about the past rather than hypothetical questions about the future. Moreover, they can imagine the outcome of such antecedents when they are prompted only by the experimenter's question and not shown the altered prop or component in question.

In considering counterfactual alternatives, how do children evaluate the impact of those alternatives on the course of events? For example, if they are asked to consider what would have happened had Teddy painted the floor with his fingers instead of a brush, how do they work out the consequences of that action? One possibility is that they draw on a body of knowledge, based on past experience, that includes information about various physical properties. For example, they might know that liquids vary in their viscosity: some liquids such as paint stick to a variety of instruments (fingers included) and can be thereby transferred to another surface; other liquids such as milk or water flow more freely. Consistent with this possibility, even 2-year-olds can work out the imaginary consequences of pretend actions such as pretend painting or pretend pouring (Harris and Kavanaugh, 1993; Leslie, 1988). This argument implies that counterfactual thinking recruits a pre-existing body of knowledge about causal sequences. However, it is compatible with Mackie's proposal that such thinking can also help to pick out the agent or instrument that led to a particular outcome. This was the issue examined in Experiment 3.

Research with adults has shown that when they hear about an agent who opts for one course of action rather than another, they are likely to consider what would have happened had the agent selected the alternative option when deciding what caused the outcome of the agent's action. For example, Wells and Gavinski (1989) presented adults with a story involving a woman's death following an allergic reaction to a celebratory meal ordered by her boss. In an experimental version of the story, her boss had wavered between two dishes of which one (unknown to him) would precipitate the allergic reaction whereas the other would not. In a control version of the story, her boss wavered between two dishes either of which would precipitate the allergic reaction. Subjects attributed a greater causal role to his choice of dish in the experimental version.

In interpreting their results, Wells and Gavinski (1989) argue that subjects can bring to mind various alternatives to what actually took place, and assess whether a given alternative would have blocked the outcome. For example, subjects might have considered a different form of celebration or a different restaurant. Most of these alternatives would have had a similar impact for both versions of the story. The two versions differed, however, with respect to one of the most obvious alternatives that subjects might bring to mind, namely the alternative choice of dish by the woman's boss. In the experimental story but not the control story, this alternative choice would have prevented the woman's death. The fact that a different causal weight was assigned to the choice of dish in the two stories provides strong inferential evidence that subjects consider counterfactual scenarios, and having identified one in which the outcome would have been avoided, focus on the difference between that contrast case and reality in reaching a causal conclusion. Thus, adults can not only work out the impact of a counterfactual antecedent, they spontaneously employ that capacity in making causal attributions. More generally, the results support Mackie's claim (Mackie, 1974) that people use the contrast between an observed sequence (in which the outcome occurred) and a counterfactual sequence (in which it did not) to pinpoint those antecedent conditions that made the difference. Experiment 3 was designed to establish whether young children display a similar pattern of causal attribution.

Subjects were presented with six stories: three in an experimental version and three in a control version. In both versions, the protagonist was offered a choice. For example, in one story Sally wanted to do a drawing, and her mother offered her a choice between a black pen and a pencil (in the experimental version) or between a black pen and a blue pen (in the control version). Sally opted for the black pen in both versions, and got ink on her fingers while she was drawing. Subjects were asked to say why the mishap occurred and also what could have been done to prevent it. It was anticipated that children would consider what the story character might have done instead when answering each question. In particular, it was predicted that children would perceive the protagonist's choice as a more important causal factor if that choice involved the rejection of an option that would have prevented the outcome rather than led to an equivalent outcome. Thus, for the story just described, children should more often refer to the failure to choose the pencil (which would have prevented Sally's fingers getting inky) than

the failure to choose the blue pen (which would have led to an equivalent outcome).

EXPERIMENT 3

8. Method

8.1. Subjects

The subjects were 32 children aged 3–4 years, equally divided into a younger group (12 boys; 4 girls) ranging from 37 to 47 months (mean = 3 years 5 months), and an older group (5 boys; 11 girls) ranging from 48 to 50 months (mean = 4 years 4 months). Children were tested in three preschools and nursery schools in Oxford, UK, serving a broad range of socio-economic backgrounds.

8.2. Procedure

Children listened to six stories in total: three in an experimental version and three in a control version. In their experimental version, the stories described a story protagonist who chose an option that would play a causal role in the story outcome, and rejected an option that would have prevented it. In their control version, the protagonist chose the same option, but rejected an option that would have led to an equivalent outcome. In all six stories the story outcome was a minor mishap.

For stories (A)–(F) the option selected by the story protagonist, the rejected option for the experimental and control versions, and the outcome of the story, were as follows: (A) a black pen (rather than a pencil or a blue pen) that resulted in inky fingers; (B) black shoes (rather than wellington boots or brown shoes) that resulted in wet socks; (C) taking brown chocolate on an outing (rather than sandwiches or white chocolate) that resulted in feeling hungry; (D) piercing paper with a pin (rather than a pencil or a needle) that resulted in a pricked finger; (E) drinking from a red glass (rather than a cup or a blue glass) that resulted in a spillage; and (F) wearing a yellow cardigan (rather than a coat or a green cardigan) outdoors that resulted in being cold. Half the children within each age group heard stories (A), (B) and (C) in their experimental version and stories (D), (E) and (F) in their control version. Half the children heard the reverse combination. The order of the six stories was randomly varied across subjects.

After listening to each story, irrespective of version, children were asked two questions. In the first (why) question, they were asked to explain the mishap described at the end of the story (e.g., "Why did Sally's fingers get all inky?"). In the second (prevention) question, they were asked to say how it might have been prevented (e.g., "What should Sally have done instead so that her fingers wouldn't get all inky?").

9. Results

9.1. References to the rejected option

Children's replies to each question were examined for references to the rejected option. They were credited with such a reference if they mentioned the rejected option, irrespective of whether that option would (control stories) or would not (experimental stories) have led to the outcome described in the story. For example, with respect to the initial (why) question each of the following replies was accepted as a reference to the rejected option: "She should have used a pencil" or "She should have used the blue one." Similarly, in reply to the second (prevention) question each of the following replies was accepted as a reference to the rejected option: "Used a pencil" or "Draw with the blue pen." To be given credit, children had to refer to the rejected option in an explicit fashion. Children who suggested avoiding the selected option but did not explicitly refer to the rejected option (e.g., "Not used the black pen") were not credited with a reference to the rejected option.

Table 3 shows the mean number of stories per child (out of three) for which children received credit as a function of Age, Story Version, and Question. Inspection of Table 3 shows that children often referred to the rejected option, especially for stories in their experimental version. Such references were especially frequent in reply to the second question when children were asked what the protagonist should have done instead but they were also made in reply to the initial (why) question. This pattern of results emerged for 3- and 4-year-olds alike.

To check these conclusions a 3-way ANOVA of Age × Story version × Question with repeated measures on the last two factors was carried out. Children cited the rejected option more often when presented with experimental as opposed to control stories (Version, $F(1, 30) = 86.79$, $p < .0001$). They also cited the rejected option more often when answering the second (prevention) question as compared with the first (why) question (Question, $F(1, 30) = 28.96$, $p < .0001$). Interpretation of these simple effects, however, must be qualified by reference to the interaction of Story version × Question ($F(1, 30) = 21.00$, $p < .0001$). Further analysis of this interaction confirmed what is apparent from inspection of the left-hand panel of Fig. 1: children cited the rejected option more often for experimental than control stories when answering the initial (why) question ($F(1, 60) = 19.954$, $p < .0001$) and the second (prevention) question ($F(1, 60) =$

Table 3
Mean number of references per child to alternative choice as a function of Age, Question and Story version (*SD* in parentheses)

Age	Experimental question		Control question	
	Why	Prevent	Why	Prevent
Younger	0.88 (1.0)	2.00 (0.8)	0.13 (0.5)	0.25 (0.6)
Older	0.81 (0.6)	1.75 (0.8)	0.19 (0.4)	0.38 (0.6)

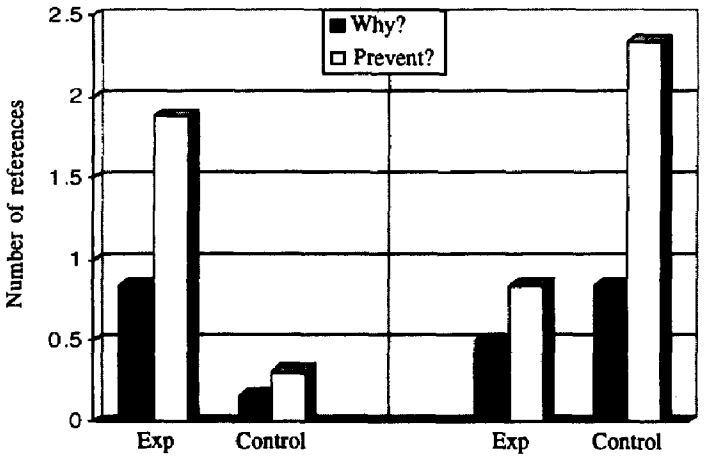

Fig. 1. Mean number of references to the rejected option (left-hand panel) and to an alternative course of action (right-hand panel) as a function of story version and question.

103.067, $p < .0001$). However, the difference between the two questions was significant for the experimental stories ($F(1, 60) = 49.953$, $p < .0001$) but not for the control stories ($F(1, 60) = 1.148$, n.s.). Indeed, children rarely cited the rejected option in reply to either question for the control stories. The above pattern was obtained for both age groups: the simple effect of age was not significant, and age did not interact with either of the other variables. Finally, a similar 3-way analysis of the data using an arcsine transformation for proportional data produced exactly the same pattern of significant findings.

9.2. References to other alternative actions

Children's references to a different course of action that the protagonist might have adopted were not confined to citation of the rejected option. They also invoked other alternatives. For example, in reply to the first question for Story A, children said: "'Cos she should have done it with a crayon" or "She shouldn't have put her hand on it (i.e., her drawing)." In reply to the second question for Story A, they said: "Draw around her hands" or "Put some gloves on." Such replies show that children consider counterfactual alternatives even when the particular alternatives are not explicitly prompted by the story content. To assess the frequency of such thinking, children's replies to each question were examined for reference to an alternative course of action. They were credited with such a reference if they appropriately indicated an alternative action or precaution that would have prevented the mishap, as in the above examples.

Table 4 shows the mean number of stories per child (out of three) for which children received credit as a function of Age, Story version, and Question. Inspection of Table 4 shows that children often referred to an alternative course of action, especially on control stories. Such references were more frequent in reply to the second (prevention) question when children were explicitly asked about an alternative course of action but they also occurred in reply to the initial (why) question.

Table 4
Mean number of references per child to an alternative course of action as a function of Age, Question and Story version (*SD* in parentheses)

Age	Experimental question		Control question	
	Why	Prevent	Why	Prevent
Younger	0.25 (0.6)	0.44 (0.6)	0.75 (1.0)	2.19 (0.7)
Older	0.75 (0.8)	1.25 (0.8)	0.94 (1.0)	2.50 (0.6)

To check these conclusions a 3-way ANOVA of Age × Story version × Question with repeated measures on the last two factors was carried out. Children proposed an alternative course of action more often when presented with control as opposed to experimental stories (Story version, $F(1, 30) = 42.42$, $p < .0001$). They also proposed an alternative course of action more often when answering the second (prevention) question as compared with the first (why) question (Question, $F(1, 30) = 61.94$, $p < .0001$). Both of these simple effects need to be interpreted in light of the two-way interaction of Story version × Question ($F(1, 30) = 18.89$, $p < .0001$). Further analysis of this interaction, illustrated in the right-hand panel of Fig. 1, showed that for the initial (why question) the simple effect of Story version fell short of significance ($F(1, 60) = 3.133$, n.s.) but for the second (prevention) question, children proposed an alternative course of action more often for control stories than experimental stories ($F(1, 60) = 59.642$, $p < .0001$). In addition, the simple effect of Question was not significant for experimental stories ($F(1, 60) = 3.762$, but for control stories children proposed an alternative course of action more often in response to the second (prevention) question than the initial (why) question ($F(1, 60) = 71.628$, $p < .0001$).

In contrast to the preceding analysis of references to the rejected option, the main effect of Age ($F(1, 30) = 7.06$, $p < .0125$) was significant. Four-year-olds proposed more alternatives than 3-year-olds. However, age did not interact with either of the two within-subject variables. As in the previous analysis, a second 3-way ANOVA using an arcsine transformation produced a similar pattern of results.

9.3. The formulation of responses to the initial (why) question

In the second (prevention) question, children were explicitly asked to suggest a different course of action, but in the initial (why) question they were simply asked why the outcome had occurred. They were free to indicate a different action or not. As shown in the preceding analyses, children often did mention a different course of action in answering this initial why question. For experimental stories, they frequently said that the protagonist need not have rejected the option explicitly mentioned in the story; for control stories, they often invoked an altogether different course of action that the protagonist might have adopted. Children formulated these replies to the initial (why) question in various way; these formulations were categorized in order to discover what was normative, and

whether there were any age changes. All references to a different course of action (whether a reference to the rejected option, or to an altogether different course of action) could be allocated to one of the following eight categories which are named in terms of a key word that appeared in the answer:

1. *Need*; for example, "Because she *needs* a coat on."
2. *Should*; for example, "She *should* have used a pencil."
3. *Want*; for example, "Because she *wanted* some sandwiches."
4. *Didn't/Wasn't*; for example, "'Cos he *didn't* have (*wasn't* wearing) his boots."
5. *Had to*; for example, "Because she *had to* have her coat on."
6. *Too*; for example, "Because it (i.e. the glass) was *too* full."
7. *Wrong*; for example, "Because she had the *wrong* cardigan on."
8. *I would*; for example, "*I would* wear my wellingtons."

Table 5 shows the percentage of replies to the initial (why) question made by each age group that fell into each category. Inspection of Table 5 shows that both age groups typically viewed the mishap as the product of an action that failed to meet a standard or norm. Thus, they said that it occurred because the protagonist had omitted to carry out a standard action (*Didn't/Wasn't*) or had deviated from an implied norm (*Should*, *Need*, *Had to*, *Too*, *Wrong*, *I would*). The main difference between the two age groups was that the 4-year-olds had converged on two linguistic formulae for such omissions or deviations (*Didn't* and *Should*), whereas the 3-year-olds used a more heterogeneous set of formulae.

Finally, children's replies to the initial (why) question were examined to check whether they spontaneously referred either to the rejected option or to other alternative actions that would plausibly prevent the outcome on the very first story, that is, before they had been asked any questions about prevention. Of the 32 children, 6 children made such spontaneous references.

GENERAL DISCUSSION

In Experiment 3, children often answered the two test questions by referring to a different action that the story character might have undertaken. This type of answer was given to the second (prevention) question, and to the initial (why) question. Subjects mentioned two types of different action. They referred to the option introduced into the story but explicitly rejected by the protagonist; they also

Table 5
Percentage of replies to the initial (why) question that fell into eachof eight categories as a function of Age

	Need	Should	Want	Didn't	Has to	Too	Wrong	I would
3 years	18.8	12.5	3.13	37.5	21.9	6.3	0.0	0.0
4 years	0.0	51.2	2.3	37.2	0.0	2.3	4.7	2.3

proposed entirely different actions that the protagonist might have taken, options not explicitly introduced into the story at all. As might be expected, the pattern of results for these two types of alternative differed for the two story versions.

References to the option rejected by the protagonist were more frequent for experimental stories. References to an altogether different course of action were more frequent for the control stories, especially in reply to the second prevention question. These findings show that when young children contemplate a causal outcome, they consider different antecedent conditions that would prevent the observed outcome. In the experimental stories, had the protagonist chosen the rejected option, the outcome would probably not have occurred. Children cited this rejected option both in explaining how the outcome came about and in saying how it might have been prevented. In the control stories, by contrast, the rejected option would not have prevented the observed outcome. Instead of referring to this rejected option, children proposed various other courses of action instead.

Analysis of children's replies to the initial (why) question showed that for both types of story children explained the mishap as the product of a failure or deviation. They said that the protagonist had not carried out a standard action or had diverged from a norm. Finally, references to either the rejected option or to another course of action were produced by some children in response to the why question on the first story – before they had been posed any questions about prevention.

Taken together, the three experiments offer a cumulative and convincing demonstration that young children, including 3-year-olds, can consider counterfactual scenarios in trying to figure out both what has caused a particular outcome and how it might have been prevented. Experiment 1 showed that 3- and 4-year-olds alike can judge whether counterfactual antecedents would have prevented an observed outcome. Experiment 2 extended earlier findings (Baillargeon et al., 1981) by showing that 3-year-olds can imagine and differentiate between antecedents that would have prevented the observed outcome and those that would still have caused it to happen. Finally, Experiment 3 showed that 3- and 4-year-olds spontaneously make the distinction between these two types of antecedent when they are asked to reflect on a causal outcome. They focus on counterfactual antecedents that would have blocked the observed outcome when asked why it happened and how it might have been avoided. Moreover, in answering these questions, children are swayed by the nature of the alternative course of action that the protagonist was offered but rejected. In both the experimental and control versions of a given story, the protagonist engaged in the same activity, used the same implement and brought about the same outcome. For example, in both versions of one story, the protagonist did a drawing, used a black pen, and ended up with inky fingers. Despite this equivalence in the actual sequence of events, the option rejected by the protagonist differed across the two versions and children analyzed the outcome differently. In the experimental versions, they were more likely to focus on the failure to choose the explicitly mentioned alternative in explaining both why the mishap occurred, and how it might have been prevented. In the control versions, they were more likely to

invoke a different course of action, one not explicitly mentioned in the story. The implication is that the two types of story prompted children to consider different counterfactual alternatives. Hence, consistent with Mackie's proposal, children listening to the experimental and control stories diverged in their conclusions about how the mishap came about and what might have prevented it.

In the Introduction, an alternative role for counterfactual thinking was considered. Mackie implies that counterfactual thinking helps to pick out a likely causal agent. A different possibility is that a causal conclusion is first reached, and is subsequently used as a basis for drawing counterfactual inferences. For example, once an outcome has been ascribed to a particular instrument, it is reasonable to draw the counterfactual conclusion that the outcome would not have occurred had that instrument not been used. According to this account, children's causal analyses precede and guide their counterfactual thinking rather than the reverse.

To what extent can the observed pattern of counterfactual thinking be explained by this alternative account? It implies that, irrespective of story version, children first identify the likely causal agent. During this initial stage, they do not need to consider circumstances in which the outcome would not have occurred in order to identify a likely causal agent. Next, having identified a likely agent, they are in a position to infer that the outcome could have been prevented had an alternative course of action been taken in which that agent was eliminated. In reviewing possible alternatives, they might recollect the option rejected by the story protagonist. If it would have blocked the outcome (as in experimental stories) they propose it as a likely preventive measure. If, on the other hand, they judge it to leave the outcome unaffected, they move on and propose other options.

This alternative account of the role of counterfactual thinking is consistent with the finding in Experiment 3 that different remedies were proposed for the experimental and control versions of the same story when the prevention question was posed. Recall, however, that children also referred to what the protagonist did not do, or should have done instead, even when answering the initial why question. Moreover, such references differed for the experimental as compared with the control versions of the same story. Yet on this alternative account it would be reasonable to expect children to ignore such counterfactual alternatives, at least when answering the initial why question.

Still, it might be possible to explain the production of counterfactual responses to why questions by arguing that children allow their knowledge of the likely impact of alternative courses of action (not actually taken by the protagonist) to guide their causal conclusions. Furthermore, although counterfactual responses to why questions did occur, they were not widespread for the very first story (i.e., before children had been asked any prevention questions). Thus, children may have been prompted to offer counterfactual responses to subsequent why questions by the pairing of the two test questions across stories. However, it is important to note that each of these arguments concedes that children do consider alternative cases and allow them to infuse their causal conclusions with minimal prompting.

In comparing Mackie's proposal with the alternative account just discussed, it will be important in future research to assess the extent to which children's

counterfactual thinking occurs spontaneously or requires prompting. At one extreme, children might spontaneously consider counterfactual alternatives whenever they initiate a causal analysis of an event. At the other extreme, they might do so only when asked to draw inferences about possible preventive measures. A third possibility is that children initiate or postpone such thinking depending on the type of causal outcome they seek to explain. Thus, children might be especially prone to engage in counterfactual thinking when they can easily bring to mind occasions when the observed outcome has not occurred or when issues of prevention are made salient (e.g., when an accident or mishap occurs as in the stories of Experiment 3).

In the remaining discussion, the proposal that children's causal thinking involves counterfactual cases will be compared to three alternative conceptions: (1) the standard Humean approach, (2) theories that emphasize children's understanding of causal powers, and (3) theories that ascribe a key role to covariation information. As noted in the Introduction, research on the emergence of causal thinking has frequently adopted a Humean framework by examining children's sensitivity to the spatial or temporal gap between an antecedent event and a consequent event. The results of Experiments 1–3 suggest that this approach provides an incomplete analysis of children's causal thinking, and the biases or constraints to which it might be prone. According to the standard approach, when children seek to explain an outcome, they focus on antecedent events that are close in space and time to the outcome. However, the present results show that young children's causal thinking, in common with that of adults, can be influenced by the mental availability of an alternative scenario – a scenario that constitutes a "near miss" in that it nearly happened. In particular, if an agent has rejected one course of action for another, and if the observed outcome is judged unlikely in the context of the rejected option, children readily identify the failure to select the alternative course of action as playing an important causal role. Subjects rarely alluded to the rejected option when it too would have led to the observed outcome. A causal analysis that is strictly governed by considerations of temporal or spatial proximity would not exhibit such an asymmetry since the actual choice stands in the same spatial and temporal relation to the outcome no matter what the rejected alternative.

This account leads to some interesting predictions. The world is so constructed that situations that run counter to a given type of observed situation vary in their frequency, and hence, in their likely mental "availability" – the ease with which they may be brought to mind (Tversky and Kahneman, 1973). Some counterfactual alternatives will be very commonplace whereas others will be highly unusual. For example, in the case of falling objects, both the presence and the absence of an initial force are easy to observe but the absence of gravity is not. If it is relatively easy to bring to mind a counterfactual antecedent that is commonplace as opposed to one that is rare, then it should be easy to contrast the presence of force with its absence but more difficult to contrast the presence of gravity with its absence. Hence, force should be more easily identified as a causal agent than gravity. The history of science supports this claim (McCloskey, 1983). Notice, however, that

nothing in the Humean analysis allows us to explicate that differential salience. Precisely because gravity is rarely absent, its effects on the trajectory of a falling object are observed all the more systematically and repeatedly than those of any initial force. The identification of such a ubiquitous causal factor ought to be simple if the Humean emphasis on the observation of regular sequences were correct. In sum, we may predict that children, will more readily identify the causal efficacy of agents that they perceive to vary in strength or availability; the invariant presence of other agents will mask their causal role.

Research both on children's naive psychology and on their naive physics lends support to this prediction. Recent evidence has shown that children ranging from 2 to 5 years elaborate a naive psychology: they come to predict and explain people's emotions, actions, and utterances in terms of desires and beliefs (Harris, 1989; Perner, 1991; Wellman, 1990). Also well established is the finding that children take account of desires before beliefs. For example, when asked to predict what emotion someone will feel toward a given outcome, children consider whether the outcome matches the person's desire before they consider whether it matches the person's beliefs and expectations (Hadwin and Perner, 1991; Harris et al., 1989; Wellman and Banerjee, 1991). This developmental pattern also emerges in children's communicative contexts. In a comprehensive analysis of children's spontaneous speech, Bartsch and Wellman (1995) report a three-phase development between 2 and 5 years: in an initial phase, English-speaking 2-year-olds systematically invoke desires in their explanations but rarely invoke beliefs; in a second intermediate phase, typically starting around the third birthday, they begin to talk about beliefs but still rarely invoke them in explaining action; in a third phase, at about 4 years they begin to invoke beliefs in their explanations. Why should young children be quicker to incorporate desires than beliefs in their explanations? A plausible explanation, in light of the above analysis, is that children find it easier to imagine a contrast case with respect to desire than belief. Agents often differ from one another in the desires that they bring to a given situation. On the other hand, agents frequently agree on the basic facts of a situation. In line with this suggestion, Bartsch and Wellman (1995) report that "desire contrastives" – utterances in which children comment on the way that a desire varies across actors are quite frequent in the initial phase, described above. Parallel "belief contrastives" emerge only in the second phase.

Turning to naive physics, we may consider children's understanding of the balance beam (Siegler, 1976). Children are shown a balance beam with varying weights on either side at varying distances from the fulcrum and asked to predict which side will go down when the beam is released. At first, children focus on the heavier object in making a decision. Only later do they start to incorporate the distance dimension. A plausible explanation is that in the context of balancing operations, children are sensitive to variation along the weight dimension to a greater extent than variation along the distance dimension. Siegler (Siegler, 1976; Experiments 3a–c) offers support for this interpretation. Five-year-olds were asked to study the distribution of weights on a balance beam, and to later reproduce that distribution on a second balance beam. Children were frequently correct in

reproducing the number of weights on each arm but incorrect in reproducing their distance from the fulcrum. Thus, young children are more likely to encode variation in weight than distance, even in a relatively simple task such as reproduction where no prediction is called for.

A different challenge to the standard Humean view has been mounted by Shultz (1982). Following Harré and Madden (1975), he argues that particular types of entity in the world are endowed with causal power or energy; the transmission of that power or energy to targets or recipients may be perceived directly rather than inferred. In a creative series of experiments, children were presented with two sources of energy (e.g., two wind blowers or two lamps) and asked to decide which of the two sources produced a given effect (e.g., blowing out a candle or making a spot on the wall) when (1) only one of the two sources was transmitting energy or (2) both sources were transmitting energy but the course of one was deflected by an obstacle such as a screen or mirror. Children, including a group aged 2–4 years, usually identified the source correctly. When asked to justify their choice, children rarely mentioned temporal or spatial contiguity between the activated source and its effect. Instead, they mostly offered justifications in terms of energy transmission: they referred to the nature of the transmission (e.g., movement of air), the source of transmission (e.g., noting that only one blower or lamp was active) or its path (e.g., noting that only one source was uninterrupted). Shultz concluded that children focus on generative transmission in identifying a cause to the neglect of Humean rules such as temporal or spatial contiguity.

However, although children mostly offered justifications in terms of energy transmission, these justifications were not simply couched in positive terms. Rather, children often pointed to a contrast between the operation versus non-operation of a candidate cause. For example, they contrasted the presence versus absence of wind (e.g., "The white one because it blowed it. The green one didn't because it didn't blow") or the presence versus absence of an obstacle to light (e.g., "The green one. The mirror blocks the light for yellow but not for green"). These justifications clearly suggest that children conceptualized the phenomenon in terms of a contrastive analysis. They noticed that the effect occurred in the presence of given type of energy but did not occur when it was inactive or blocked.

Shultz (1982) also devised experiments in which he attempted to pit covariation information against information about energy transmission. Thus, by means of an experimental ruse, a lamp whose presence versus absence covaried with the presence versus absence of a spot of light on the wall proved not to be on in another experimental phase. Overall children tended to explain the presence of the spot of light in terms of the information available in each phase, focusing on which lamp was present in one phase, or alternatively on which lamp was on in the other phase. Nonetheless, there was a tendency to be more swayed by information about energy transmission, that is, information about which lamp was on.

However, this result does not rule out an important role for covariation information in identifying a given energy source. Children might know – from using the type of before and after comparison described in the introduction – that a

spot of light appears only after a light source is activated; for example, a torch is turned on or a light-switch is depressed. In line with this interpretation, the generative transmission justifications that predominated were often couched in terms of the contrast between an active and an inactive source: "Red [lamp], because the red one was open; the blue one was closed."

More generally, the opposition between generative transmission information and covariation information that Shultz introduces may be misleading. That opposition will rarely occur except in an environment contaminated by experimental trickery. To be precise, an informative causal encounter will have the following components: information about the occurrence or non-occurrence of an outcome, independent information about the activation or non-activation of a candidate causal agent, and the possibility of comparing outcomes in the presence versus absence of activation. Consider, for example, a candle that goes out. The child can compare outcomes for the candle before and after the activation of a possible cause such as blowing on the candle. Alternatively, consider a spot of light that appears on the wall. The child can compare outcomes before and after the activation of a possible cause such as pressing a torch- or light-switch. In either case, the child has the basic covariation information to identify a cause.

Finally, the present account may be compared to recent theorizing on adults' use of covariation information. Cheng and Novick (1991), Cheng and Novick (1992) argue that when adults identify the cause of an outcome, they compare the likelihood with which an effect occurs in the presence of a candidate cause and fails to occur in its absence. Like the present account, this proposal builds on suggestions made by Mackie (1974) and the related arguments of Hart and Honoré (1959/1985). Cheng and Novick emphasize that causal analyses depend on the selection of a set of events for analysis and comparison – what they refer to as the focal set. The focal set will include instances in which the outcome is and is not observed. The focal set is not fixed, so that different conclusions may be reached depending on the choice of set. For example, as noted in the Introduction, oxygen is not normally considered as the cause of a fire. In Cheng and Novick's terms, this is because it will typically be present for all instances of the focal set. However, if a fire has occurred in a laboratory where special precautions are taken to exclude oxygen then the focal set is likely to be composed of one instance in which oxygen has leaked and a fire ensued, and many in which oxygen has been excluded and no fire observed. Granted this covariation, the presence of oxygen is likely to be deemed a cause of the fire. Finally, Cheng and Novick develop the notion of a variable focal set to analyze the distinction between causes and enabling conditions. Specifically, they point out that an enabling condition can be invariably present across one focal set, but variably present across another. Thus, although the focal set for most fires will include only instances in which oxygen is present, there are other possible focal sets (as in the case of the laboratory fire) where its presence is variable. Thus, oxygen will be identified as an enabling condition for an ordinary fire, because even though its causal efficacy cannot be assessed for many focal sets (granted its invariable presence) it is known to covary with fire in some other focal set.

Combining the present developmental findings with the analysis of adult causal

thinking offered by Cheng and Novick (1991), Cheng and Novick (1992), a key feature of causal thinking remains stable across the lifespan. Admittedly, adults may extend the focal set over a greater range of instances; they may consider more than one focal set so as to differentiate between causal and enabling conditions; and they may make the relevant probability estimates more accurately. Indeed, adults can sometimes be exquisitely accurate in the causal conclusions that they draw from covariation information (Wasserman, 1990) whereas young children have difficulty in computing that information accurately (Siegler and Liebert, 1974; Shaklee and Mims, 1981). Nonetheless, the nub of the process – an assessment of whether an outcome occurs in the presence as compared with the absence of a candidate cause – may remain stable throughout development. In line with this conclusion, Shultz and Mendelson (1975) showed that children can use such information to work out which of two candidate causes produces an effect. For example, pulling one of two levers A and B appeared to cause a light to go on. Over a series of trials, children were shown that the light consistently came on when lever A was depressed and consistently did not come on if it was not depressed. By contrast, the light was inconsistently associated with depression of lever B. Even 3-year-olds correctly attributed the effect to A.

A possible objection to this continuity thesis is that young infants can detect causal relationships between events and yet they are not likely to be capable of counterfactual thinking. Thus, when infants repeatedly watch a direct launching in which an agent strikes a target and sets it in motion, they appear to interpret that event in causal terms (Leslie and Keeble, 1987; Oakes and Cohen, 1990). These results suggest that the perception of causality in infancy is triggered by specific spatio-temporal parameters of the launching, and does not involve any putative contrast between the observed event, and some other comparison event.

However, this objection may underestimate the infant's analytic capacity. As described in the Introduction, a contrastive analysis can often be based on a before-and-after comparison. Specifically, the onset of a causal event and its ensuing effect can be compared with the stable situation immediately beforehand. In the period before a launching infants continually see the absence of any spatial contact between the moving agent and the target, and they also see a motionless target. On the other hand, as soon as contact between the moving agent and the target occurs, the target immediately moves. This contrast provides a basis for the conclusion that targets remain stationary until they are hit by an agent. An infant who encodes the event in this way should dishabituate to inconsistent events: movement of a target prior to its being hit by the agent, or conversely a lack of movement by a target immediately after being hit by the agent (as in delayed launching). This is the pattern of results reported by Oakes and Cohen (1990). In making a similar argument, Cheng (1993) has pointed out that Michotte's original experiments with adults on the launching effect confirm that events that disrupt the perceived contrast between the before and after periods also disrupt the perception of launching. For example, if the target moves independently as the agent travels toward it, perception of the launching being caused by contact is suppressed (Michotte, 1946/1963).

In conclusion, the results of Experiments 1–3 show that young children readily

interpret the cause of an outcome in terms of a contrast between the observed sequence of events, and a counterfactual alternative in which the outcome did not occur. Their sensitivity to such contrasts is consistent with recent findings on children's naive psychology and naive physics. In principle, this mode of thinking might also apply to infant's perception of causality. Future research will establish just how far Mackie (1974) has identified a mode of causal thinking that is primitive and fundamental rather than providing an addendum to Hume's influential emphasis on spatio-temporal contiguity.

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Appendix 1

Episode 2

One day the tree was standing up like this (Experimenter points to an upright toy tree). But guess what! There was a storm and the wind came along and blew the tree over like this (Experimenter blows tree over).

Now control question: Is the tree standing up now?
Before test question: Was the tree standing up before?
Test question: What if the wind had not come – would the tree be standing up?

Episode 3

One day Henry the hippo has some chocolate. he holds the chocolate in his mouth like this (Experimenter points to a toy hippo with a piece of chocolate between its jaws). But guess what! He drops the chocolate and it falls on the floor (Experimenter makes chocolate drop from hippo's mouth).

Now control question: where is the chocolate now. Can you show me?
Before control question: Where was the chocolate before? Can you show me?
Test question: What if Henry had not dropped the chocolate – where would the chocolate be? Can you show me?

Episode 4

Robert the bunny rabbit lives in this box (Experimenter points to toy rabbit in box). But guess what! One day the door is not shut properly. So the bunny rabbit opens the door and he goes to sit here, outside the box (Experimenter puts rabbit outside box).

Now control question. Where is the bunny rabbit now? Can you show me?
Before control question. Where was the bunny rabbit before? Can you show me?
Test question. What if the door of the box had been shut properly – where would the bunny rabbit be? Can you show me?

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