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Counterfactual Reasoning: Developing a sense of “nearest possible world”

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Abstract

We investigated at what point in development 3- to 6-year-old children begin to demonstrate counterfactual reasoning by controlling for fortuitously correct answers that result from basic conditional reasoning. *Basic conditional reasoning* occurs when one applies typical regularities (such as “If <whenever> it doesn’t rain the street is dry”) to counterfactual questions (such as “If it had not rained, would the street be wet or dry?”) without regard to actual events (for example, if street cleaners had just been washing the street). In *counterfactual reasoning*, however, the conditional reasoning must be constrained by actual events (according to the “nearest possible world”). In situations when counterfactual reasoning and basic conditional reasoning would yield the same answers, even the youngest children gave mostly correct answers. However, tasks in which the two reasoning strategies resulted in different answers proved unusually difficult even for the older children.

People often reflect on how an event in the past might have turned out differently. Creating such alternatives to known facts is called counterfactual reasoning (Roese, 1997). Although it is common among adults, it is still not clear what is necessary for proper counterfactual reasoning. This is a serious shortcoming because counterfactual reasoning is relevant in many different areas such as cognitive psychology, social psychology, developmental psychology, and philosophy.

Developmental psychologists have addressed this issue by exploring whether children’s counterfactual reasoning abilities are related to their understanding of causation (German, 1999; Harris, German, & Mills, 1996; Kavanaugh & Harris, 2000), their understanding of false belief (Grant, Riggs, & Boucher, 2004; Guajardo & Turley-Ames, 2004; Müller, Miller, Michalczyk, & Karapinka, 2007; Perner, Sprung, & Steinkogler, 2004; Riggs, Peterson, Robinson, & Mitchell, 1998), their feeling of regret and relief (Amsel et al., 2003; Amsel & Smalley, 2000; Guttentag & Ferrell, 2004), their understanding of counterfactual and actual worlds as alternative possibilities at a certain time in the past (Beck, Robinson, Carroll, & Apperly, 2006; Byrne, 2005), or their executive functions such as inhibitory control (Beck, Riggs, & Gorniak, in press) and working memory (German & Nichols, 2003; Robinson & Beck, 2000).

The majority of these developmental studies assessed the ability to reason counterfactually by telling a short story (for example, “Carol made the floor all dirty with her shoes”) and then asking a subjunctive question about the past (or present): “If Carol had taken her shoes off, would the floor be dirty or clean?” (Harris et al., 1996). Children’s main error was to answer with what was actually the case in the story, that is, that the floor was dirty (referred to as a “reality error”). The predilection for reality errors subsides between 3 and 5 years,

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although the exact age varies across studies. However, in studies that assessed the reasoning differently (such as showing counterfactual emotions like regret), children showed difficulties with some counterfactual tasks until 6 years or older (Amsel et al., 2003; Amsel & Smalley, 2000; Beck et al., 2006, open counterfactuals; Guttentag & Ferrell, 2004). This discrepancy reveals a shortcoming in existing studies: they fail to distinguish between the kind of reasoning the experimenter intended to investigate and the kind of reasoning the children employed.

Answering a subjunctive past question correctly shows that children can reason with conditionals (for example, if X is F then Y is G) and that they can do so independently of what the actual states of X and Y are. This demonstrates an ability to entertain counterfactual states, but that ability is not the same as counterfactual reasoning. All *kinds* of conditional reasoning can depend on assumptions that are not currently true; this is not limited to counterfactual reasoning. For instance, the developmental literature considers a question about the future—"If X will be F then Y will be ...?"—to demand future hypothetical reasoning (Riggs et al., 1998), and studies have consistently found these questions to be much easier than subjunctive questions about the past. Another kind of conditional, rarely discussed in the developmental literature, is the universally quantified conditional expressing a general regularity, which is typically formulated in the present tense indicative. "If X is F then Y is G" can be read to mean that whenever X is F then Y is G, without reference to any particular instance at a particular time. Reasoning with such universals demands what we call "basic conditional reasoning."

The problem with previous investigations is that, although they used a subjunctive past question, children might have applied basic conditional reasoning and arrived at the same answers. For instance, when an investigator asks out of the blue, "If Carol had taken off her shoes, would the floor be dirty or clean?" a child could answer with "(probably) clean" by use of basic conditional reasoning, applying "If (whenever) people take off their shoes floors tend to stay clean" to the case of Carol. Children often interpret experimenters' instructions not as intended but in a pragmatic way. For instance, Romain, Connell, and Braine (1983) pointed out that children interpret "if" pragmatically. They often interpret the statement "If you mow the lawn, then I will give you five dollars" to mean "If you do not mow the lawn, then I won't give you five dollars." In other words, they try to figure out what the speaker actually means by the sentence. On the basis of these assumptions, they draw conclusions, for example, that if they do not mow the lawn, they won't earn money. Although this conclusion is not logically valid, it would be true in most situations. Basic conditional reasoning is, of course, only a minimal instance of reasoning because it consists of two simple processes: (1) memory retrieval, which is at best a prerequisite for logical reasoning (Markovits & Barrouillet, 2002), not an act of reasoning in itself; and (2) the simple logical reasoning rule of universal instantiation.

What abilities do children need in order to demonstrate proper counterfactual reasoning? David Lewis (1973) proposed that, unlike normal conditionals whose truth depends on the real world, the truth of counterfactual claims is determined by what is true in the *nearest possible world* (that which resembles the real world most closely). Consider the sentence "If Carol had taken her shoes off, the floor would have stayed clean." This is true only if, in a possible world in which Carol had taken her shoes off (but is otherwise as similar as logically possible to the actual world), the floor would have stayed clean. The counterfactual claim is false if there is some nearer possible world, where Carol removed her shoes but the floor was still dirty—if, for instance, before Carol entered the room with her dirty shoes her nasty brother had already messed up the floor with *his* dirty shoes. Hence, in this nearest possible world, even though Carol takes off her shoes, the floor is still dirty. With counterfactual reasoning, we would thus conclude that the floor would have been dirty, a

conclusion that basic conditional reasoning would not have produced. We think that developmental investigations must distinguish more clearly between counterfactual and basic conditional reasoning.

There is consistent evidence in the developmental literature that children become capable of answering indicative future questions (requiring future hypothetical reasoning) before 3 years of age. This is reliably earlier than they can answer past subjunctive questions (Beck et al., 2006; Perner et al., 2004; Riggs & Peterson, 2000; Riggs et al., 1998; Robinson & Beck, 2000; Study 1), which tend to elicit the reality error. There are several points of difference that may make counterfactual reasoning particularly difficult, especially for children. First, the counterfactual assumption, by definition, contradicts with the corresponding fact (Carol took her shoes off – Carol was wearing her shoes), whereas in future hypothetical reasoning the corresponding fact in the future is not yet known. Second, the use of the subjunctive mood signals that the real sequence of events cannot be ignored, but must play a role in the counterfactual reasoning process. This requires that two different models of the world stay simultaneously active (Beck et al., 2006; Byrne, 2005), which requires more information-processing capacity and is likely to intensify the interference of known facts with counterfactual assumptions more than if hypothetical assumptions happen to differ from reality. Researchers have amply documented the problems created by the interference of reality with the process of counterfactual assumption and conclusion for very young children of 2½ to 5 years (Beck et al., 2006; Perner et al., 2004; Riggs & Peterson, 2000; Riggs et al., 1998; Robinson & Beck, 2000; Study 1). Finally, the real sequence of events that is being counterfactually altered must be kept active for a good reason. It plays an important role in how the counterfactual model needs to be constructed, which developmental psychology has yet to investigate but is hotly debated in philosophy.

The last point especially may explain the existing discrepancy in study results about the onset of counterfactual reasoning. Children master some counterfactual problems (past subjunctive questions) very early, at the age of 3½ to 4½ years (Beck et al., 2006, standard counterfactuals; German, 1999; German & Nichols, 2003; Harris et al., 1996; Perner et al., 2004; Riggs et al. 1998), but some investigations show little sign of counterfactual thinking before the age of 6 years (Amsel et al., 2003; Amsel & Smalley, 2000; Beck et al., 2006, open counterfactuals; Guttentag & Ferrell, 2004).

One way of making sense of these discrepancies is to assume that even the youngest children are able to reason counterfactually but are prevented from showing their prowess on more difficult problems; scholars have suggested two possible reasons for this. One is that children (German, 1999; Guttentag & Ferrell, 2004), like adults (Roese, 1997), tend to be more likely to engage in counterfactual reasoning for negative outcomes than for positive outcomes. However, Kavanaugh and Harris (2000; Harris 2000) tested this hypothesis directly and found no difference in children's ability to use counterfactual reasoning for negative and positive outcomes. The other suggestion comes from German and Nichols (2003), who provided evidence that because of children's working memory limitations, the length of the inferential/causal chain from the counterfactual assumption to the predicted outcome affects children's ability to engage in counterfactual reasoning.

In contrast, Perner and Rafetseder (submitted; Perner 2000) worked from the premise that younger children *cannot* reason counterfactually and suggested that these children's correct answers to past subjunctive questions might be based on basic conditional reasoning (using our terminology). Depending on the particular task, children were more or less likely to make suitable background assumptions leading to the same answer that counterfactual reasoning would produce, which made their answers look like evidence for counterfactual reasoning. The early use of basic conditional reasoning may explain why some studies show

little sign of counterfactual reasoning before the age of 6 years, provided that we can show that counterfactual reasoning takes the nearest possible world constraint into account. In order to provide more decisive evidence for counterfactual reasoning in children, we designed stories in which counterfactual reasoning produces different answers than basic conditional reasoning does.

Experiment 1

The principal objective of the present study was to determine whether children can answer “counterfactual” subjunctive questions about a past event correctly when a basic conditional reasoning approach yields a different answer. We used two different story worlds, the *sweets story* and the *dwarf story*. In each story world, four different sequences of events could take place, and each sequence comprised two component events, in this case, two transformations of an object’s location. For instance, in the *sweets story*, mother puts sweets regularly on either the top shelf or the bottom shelf (the first transformation), and then either the tall boy or the little girl comes looking for the sweets and then takes them into his or her room (the second transformation). The tall boy can reach both shelves, so he can take the sweets into his room regardless of where mother puts them. The little girl, however, is too short to reach the top shelf, and can reach only the bottom shelf. Thus, if she comes looking for the sweets, either they will remain on the top shelf or she will take them from the bottom shelf into her room. Figure 1 shows the particular structure of these story worlds.

We can see that in the case of the girl looking for the sweets, the subjunctive past question about the boy, “If not the little girl but the tall boy had come along looking for sweets, where would the sweets be?” gives the correct answer “in the boy’s room.” This answer would also result from basic conditional reasoning: “If <whenever> the boy comes looking for the sweets, they end up in his room.” However, matters are different in the complementary cases in which we ask a subjunctive past question about the girl. Children who are aware of the counterfactual nature of the question—those who know to be selective of the different possible worlds—would answer with “in her room” when sweets had been on the bottom shelf but with “on the top shelf” when sweets had been there. In contrast, children using basic conditional reasoning, despite the subjunctive mood of the question, will give the same answer in both cases, whether the sweets were on the top or the bottom shelf. What their answer will actually be depends on which background assumptions they are more likely to make. If they assume that the sweets are where the girl can reach them, the completion of “If <whenever> the girl comes looking for sweets, ...” is “...they end up in the girl’s room” regardless of where they had been at the beginning. However, when the background assumption is that the sweets are where the girl cannot reach them, then the consequent is that the sweets will be on the top shelf. We do not yet know what background assumptions children are likely to make, as this remains an empirical issue. However, whatever they prefer, as a result of the fixed background assumptions, they should give the same answer in both cases, regardless of where mother puts the sweets. Importantly, this means that we can distinguish between children who employ counterfactual reasoning and those who apply basic conditional reasoning to answer our subjunctive past questions.

Method

Participants—The sample consisted of 33 children (15 boys, 18 girls) from three different nursery schools in the area of Salzburg and Upper Austria, between the age of 2;11 (years; months) and 5;9. The children had a mean age of 4;4 with a standard deviation of 9 months. For the later analysis, the overall sample was split into two age groups. The age of the 16 children in the younger group ranged from 2;11 to 4;4 ($m = 3;8$, $SD = 0;4$), and the 17 children in the older group were between 4;5 and 5;9 ($m = 4;11$, $SD = 0;6$).

Materials—We used two different wooden models built on 42cm × 30cm wooden platforms. The model for the *sweets story* consisted of a cupboard with a shelf centrally placed and two boxes, a brown one standing on the shelf and an orange one standing beneath the shelf. For acting out the story, we used sweets and two dolls, a female one and a male one twice as tall as the female one. Each doll had its own room including a table and a photo of itself.

The model for the *dwarf story* consisted of two huts, one made of wood and one made of stone, and a large walnut tree standing behind the huts. For acting out the story, we used walnuts, a dwarf, and a squirrel. The dwarf lived in the dwarf village (three houses were drawn on a piece of cardboard) and the squirrel lived in a nest in another tree.

Design—We tested all children in two sessions approximately two days apart; sessions lasted about 15 minutes. We administered the two story worlds and the four different event sequences in each story world in fully counterbalanced order, and both story worlds were administered in each session. We tested children with a total of eight indicative future questions and eight subjunctive past questions. In fact, all eight subjunctive past questions required counterfactual reasoning, but children could get away with basic conditional reasoning for six of the subjunctive past questions: in conditions 2 and 4 (see Table 1) and in either condition 1 or 3; it is not yet clear which one of the two conditions the children will favor, as this depends on the background assumptions children make.

Procedure—We tested each child in a quiet area away from the other children. We explained the *sweets story* as follows: These are Simon and his little sister Julia. Both like sweets very much. When their mother buys sweets, she puts them *either* in a box on the top shelf *or* in a box on the bottom shelf. The boy can reach both shelves. Look, when he finds some sweets he brings them into his room. His little sister is not tall enough to reach the top shelf. She can only reach the bottom shelf. If she finds some sweets, she brings them into her room.

The *dwarf story* is about a dwarf who lives in a dwarf village and a squirrel that lives in a nest in a tree. Both like nuts very much. In search of nuts, they come to a nut tree under which two huts are built. In the roof of each hut there is a hole through which nuts fall inside. The dwarf can open the door of each hut in order to get in, collect the nuts, and bring them to his village. The squirrel, unfortunately, cannot open the doors of the huts. However, through a tiny hole in the wooden hut, it can squeeze inside to collect the nuts and bring them to its nest.

Children had to answer a total of seven control questions per story world to ensure that they had remembered all details, such as (1) Which one is the boy's room? (2) Which one is the girl's room? (3) From which shelf can the boy take sweets? (4) Where does he bring the sweets? (5) From which shelf can the girl take sweets? (6) Where does she bring the sweets? (7) Why is the girl unable to take the sweets from the top shelf? Examiners corrected wrong answers and familiarized the children by repeating the story (two times at maximum) until they answered all control questions correctly.

After the children became familiar with the structure of a story world, testing started with different events, resulting from the combination of where the object of desire was located (L1, L2) and which character came to collect it (C1/2, the character that can reach each location, and C2, who can reach only location L2). For each event, we asked indicative future and subjunctive past questions. For instance, (condition 1): "Today the box on the bottom shelf is empty. There are only sweets in the box on the top shelf." At this point we asked the children the following questions:

MEMORY 1: “Where are the sweets now?”

INDICATIVE FUTURE¹: “What will happen to the sweets when the boy comes looking for sweets?”

After the child has given an answer, this event is played out: “Look! This time the boy comes along, looking for sweets. He finds them in the box on the top shelf and takes them to his room!”

MEMORY 2: “Where are the sweets now?”

SUBJUNCTIVE PAST¹: “But what if not the tall boy but the little girl had come along looking for sweets, where would the sweets be?”

Table 1 shows the expected answers for each condition depending on whether children use counterfactual or basic conditional reasoning to answer the subjunctive past question.

Results

Control and Memory Questions—The children answered the different control and memory questions almost perfectly (above 95%) on the first trial. They appeared to have a good understanding of how the story structure worked. We checked that the exclusion from our analysis of children who answered incorrectly had no influence on our results.

Indicative Future Questions—Performance on the indicative future questions of the *sweets story* (94% correct) and of the *dwarf story* (96% correct) was not significantly different (Wilcoxon signed ranks test: $Z(N = 33) = -1.0$, $p = .32$, Cohen’s $d = .17$). Eleven children made one mistake (out of eight questions), thus they answered 253 out of 264 questions (almost 96%) correctly. However, there was a significant difference between the four conditions (see Table 1) that asked indicative future questions (Friedman test: $\chi^2(3, N = 33) = 27.4$, $p < .01$, partial eta squared $\eta_p^2 = .28$). The children made 10 mistakes in condition 2, where the character C2 could not reach the item in location L1, such as when mother had put the sweets on the top shelf: “What will happen with the sweets now, when the little girl comes looking for sweets?” The younger children in particular had some difficulty understanding that the sweets would stay on the top shelf. Nevertheless, they answered 75% of the indicative future questions in condition 2 correctly—every child answered at least one of the two questions correctly—compared to the older group, who answered 87.5% of the questions correctly. Clearly, most of the younger and practically all of the older children understood that the item stays in L1 when the C2 character comes. Children who answered only one of these indicative future questions correctly did not perform significantly differently on the corresponding subjunctive past question (the tall boy had come to take the sweets from the top shelf L1 to his room: “What if not the tall boy but the little girl had come along, where would the sweets be?”—in L1) from those children who answered both of the indicative future questions correctly (Mann-Whitney test: $U(n_1 = 10, n_2 = 23) = 100$, $p = .24$, Cohen’s $d = .43$). We checked that exclusion of the 10 children who answered the indicative future question of condition 2 incorrectly had no influence on the interpretation of results.

Subjunctive Past Questions—Children had noticeably more problems with the subjunctive past questions, where they gave correct answers to 55% of the questions in the *sweets story* and 46% in the *dwarf story* (Wilcoxon signed ranks test: $Z(N = 33) = -1.5$, p

= .13, Cohen's $d = .28$). Thus, they answered only 50% correctly compared to 96% of the indicative future questions (Wilcoxon signed ranks test: $Z(N = 33) = -5.0$, $p < .01$, Cohen's $d = 2.34$). However, performance is above chance if we consider the chance level to be at 25% (four possible answers: L1, L2, G1, and G2). The older children gave more (58.8%) correct answers than the younger children (42.1%) (Mann-Whitney test: $U(n_1 = 16, n_2 = 17) = 63$, $p < .01$, Cohen's $d = .89$). Figure 2 shows children's performance on the subjunctive past questions, split up by the four different conditions (averaged over the two story worlds).

We found that particular conditions had significant effects in the subjunctive past questions (Friedman test: $\chi^2(3, N = 33) = 53.9$, $p < .01$, partial eta squared $\eta_p^2 = .55$). Condition 1 differed significantly from all the other conditions (Wilcoxon signed ranks test for condition 2: $Z(N = 33) = -4.8$, $p < .01$, Cohen's $d = 1.81$; for condition 3: $Z(N = 33) = -4.4$, $p < .01$, Cohen's $d = 1.28$; for condition 4: $Z(N = 33) = -4.6$, $p < .01$, Cohen's $d = 1.54$), but conditions 2, 3, and 4 did not differ significantly from each other (Wilcoxon signed ranks test for condition 2 and 3: $Z(N = 33) = -1.8$, $p = .07$, Cohen's $d = 0.31$; for condition 2 and 4: $Z(N = 33) = -1.0$, $p = .3$, Cohen's $d = 0.17$; for condition 3 and 4: $Z(N = 33) = -1.2$, $p = .3$, Cohen's $d = 0.20$).

Our results show that children had severe difficulties, especially with subjunctive past questions where the C2 character could not reach the sweets at L1 (condition 1): for example, mother has put the sweets in the top shelf (L1), and the boy came and took them to his room (G1): "If not the boy but the little girl had come along looking for sweets, where would the sweets be? — in L1." The children answered only four out of 66 questions (6%) correctly, which is clearly below chance. The common error—as predicted if children engage in basic conditional reasoning and use the default assumption that each character takes sweets to his or her room—was to say that sweets would have ended up in the C2 character's room, location G2 (39 out of 66 questions = 59%; 64% of these children had answered with G2 in condition 3 too). The children answered 10 out of 66 questions (15%) with the actual location (G1: realist error) and 13 questions (20%) with the bottom shelf (L2).

In comparison, children gave 40 correct answers to 66 subjunctive past questions (61%) when the C2 character could have reached the sweets (condition 3). This is not surprising if we assume that they applied basic conditional reasoning with a default assumption that sweets tend to end up in the respective character's room. When we asked, "But what if not the little girl but the tall boy (character C1/2) had come along looking for sweets ...?", we expected most children to answer that the sweets would then be in the boy's room (location G1) regardless of where mother had put them, and 73% in condition 2 and 65% in condition 4 gave the expected G1 answer.

To summarize, children responded correctly above chance levels in conditions 2, 3, and 4 but below chance in condition 1. This pattern of results conforms strongly to what we expected under the assumption that children solve problems by basic conditional reasoning (see Table 1). To provide evidence of the participants' limited counterfactual reasoning skills, despite their knowledge of how the relevant transformations work, we compared the answers to subjunctive past questions, for example in condition 1 with the answers to the corresponding indicative future questions, in this case in condition 2. All four comparisons were highly significantly different (Wilcoxon signed ranks test: Z score = -3.7 to -5.1 ; Cohen's $d = 0.83$ to 2.81). It seems that the children generally understood the constraint on the girl (which we tested by indicative future, control, and memory questions), but were unable to create the correct counterfactual assumptions to infer that if C2 had come she would not be able to retrieve the sweets from L1.

Discussion

Experiment 1 demonstrates two clear effects. One of these is the replication of the difference between the number of correct answers on indicative future questions and on subjunctive past questions also found in studies by Perner et al. (2004), Riggs and Peterson, (2000), Riggs et al. (1998), and Robinson and Beck (2000; Study 1). The other clear effect is that performance on the subjunctive past questions can be very different within the same story world. Children give mostly correct answers if they can derive them by basic conditional reasoning from preferred default assumptions.

In condition 1 (top shelf, boy comes, takes sweets: If the little girl had come ...?), the preferred default assumption leads to a wrong answer (girl's room). To get it right, children have to consider where mother had actually put the sweets. In other words, they have to construct a possible world that is maximally similar to the actual world, one that takes account of where the sweets had actually been put. Most children in Experiment 1 failed to do this, in apparent violation of Lewis's "nearest possible world" criterion.

Experiment 2

The results of Experiment 1 showed that most children younger than 6 did not use counterfactual reasoning but used basic conditional reasoning aided by background assumptions suitable for three but not all four conditions. One worry, however, is that children capable of counterfactual reasoning might have been trapped into unthinkingly using the simplified rule that the sweets end up in the searching character's room because this is the case in three of four event sequences. This is due to an asymmetry in the structure of the story worlds of Experiment 1 (see Figure 1). There are three event sequences in which the item is transferred to the protagonist's room (location G1 and G2) but just one event sequence in which the item stays in its initial location (location L1), and this condition caused children specific difficulties when we asked them counterfactually in Experiment 1. To eliminate any possibility that children might perform badly because the one condition was an exception, we modified the structure of the story worlds for Experiment 2 so that it was symmetrical. Thus, the structure of Figure 1 changed so that the line labeled C1/2 connecting L2 with G1 now also becomes self-reflective on L2; for example, the boy is no longer able to reach the sweets when they are at the bottom shelf, and therefore the sweets stay at L2. Because he can reach only L1, the C1/2 character becomes a C1 character.

If children's basic conditional reasoning and their preferred background assumptions led to the many errors in condition 1 of Experiment 1 (where the counterfactual character could not reach the sweets), then in this experiment, children should commit most of their errors in conditions 1 and 4. However, if children reasoned counterfactually in Experiment 1 but were misled by the fact that the sweets ended up in the character's room in three out of four event sequences, then their errors in Experiment 2 should be equally distributed over the four conditions, because now the sweets remain on the shelves and are brought to the characters' rooms an equal number of times.

There is a further reason for running this experiment. Children's problems with condition 1 in Experiment 1 indicated that they apparently disregarded the first transformation (where mother put the sweets) when asked a subjunctive past question about the second transformation (if the little girl had come). This might have happened for different reasons. Children may simply have had difficulty remembering where mother had put the sweets. Although we could show in Experiment 1 that children had few problems answering indicative future, memory, and control questions—implying that they knew the rules of the story world—it might be that they were unable to retrieve this information when we asked the subjunctive past question. Conversely, children may simply have failed to look further

into the past than the counterfactual assumption led them to do. For instance, one can imagine that children, when asked what would have happened if the girl instead of the boy had come, would focus on this point in the story and the ensuing consequences of this counterfactual assumption, and ignore the facts earlier in the story, i.e., whether the sweets had been on the top or the bottom shelf. A third possibility is that children did not understand that a subjunctive past question requires them to think of the actual events in the story world in order to arrive at a correct answer. If the first or second factor was the reason that prevented children from reasoning counterfactually, then making the earlier transformation (mother puts sweets into L1 or L2) counterfactual should solve their problems. So, for example, when we ask “But what if sweets had been on the bottom instead of the top shelf?”, children need not look further into the past; moreover, the current location of the sweets reminds them of who had come to collect the sweets. However, if the third factor was the reason for giving the wrong answer, then the children should now have problems with conditions 1 and 4 even when the first transformation is taken counterfactually. To test this, we introduced subjunctive past questions about the first transformation, where mother had put the sweets.

Method

Participants—Thirty-two children (19 boys, 13 girls) from two different preschools and nursery schools in Upper Austria, between the age of 5;0 (years; months) and 6;5, participated in this study. They had a mean age of 5;10 with a standard deviation of 4 months. All participants were monolingual German speakers and came from working- and middle-class backgrounds. For the later analysis, the overall sample was split into two age groups. The 15 younger children were between the ages of 5;0 (years; months) and 5;9 ($m = 5;6$, $S.D. = 0;2$), and the 17 children in the older age group were between 5;10 and 6;5 ($m = 6;1$, $S.D. = 0;2$).

Materials—We used the same materials as in Experiment 1, except that the *dwarf story* contained only the stone hut, not the wooden hut.

Design—We tested all children in one 20-minute session during which we presented both story worlds (*sweets story* and *dwarf story*) and asked children eight control questions per story world. We used the same seven as in Experiment 1, with an additional question: “Why is the boy unable to take the sweets from the bottom shelf?” We gave each child four event sequences, two per story world, and we asked two test questions per sequence: an indicative future question (the same as in Experiment 1) and a subjunctive past question about either the first (“What if sweets had not been at L1 but at L2?”) or the second transformation (“What if not C1 but C2 had come?”). Thus, each child answered four subjunctive past questions, two in which the location was the counterfactual element (for one story world the character could have reached the item, and for the other story world the character could not), and two in which the character was the counterfactual element (for one story world the character could have reached the item, and for the other story world the character could not). We used a Latin square design to control for variation.

Procedure—The procedure was basically the same as in Experiment 1, save for two modifications. In the *sweets story*, the tall boy had broken his leg and could not kneel down to reach the sweets on the bottom shelf. In the *dwarf story*, there was only one hut, the stone one whose door the dwarf can open to collect nuts. The squirrel cannot open the door of the stone hut but can climb up the tree to get to the nuts, whereas the dwarf is overweight and is unable to climb the tree. All nuts are *either* in the stone hut *or* on the tree.

Results

Control and Memory Questions—Children's performance in the control and memory questions of the *sweets story* and the *dwarf story* was excellent and practically identical for both story worlds, 98.4% versus 99.2%.

Indicative Future Questions—Children's performance on the indicative future questions was very good and did not differ significantly between the two story worlds (*sweets story*: 100% correct; *dwarf story*: 91% correct) (Wilcoxon signed ranks test: $Z(N=32) = -1.9$, $p = .06$, Cohen's $d = .35$). Two children made one mistake out of four questions, whereas two children made two mistakes; thus, overall children answered almost 96% of the questions (122 of 128) correctly. Children did not perform significantly differently on indicative future questions, where the character is or is not able to reach the item (Wilcoxon signed ranks test: $Z(N=32) = 0.0$, $p = 1.0$). Children seemed to understand that in some scenarios the item stays where it is; only the youngest age group in Experiment 1 had problems with the indicative future questions where the item stayed in its location.

Subjunctive Past Questions—Children gave 59% correct answers to the subjunctive past questions in the *sweets story* and 75% in the *dwarf story* (Wilcoxon signed ranks test: $Z(N=32) = -1.8$, $p = .08$, Cohen's $d = .31$). The Wilcoxon signed rank test showed a highly significant difference between answers to indicative future (96% correct) and to subjunctive past questions (63%) ($Z(N=32) = -4.5$, $p < .01$, Cohen's $d = 1.41$). Improvement on subjunctive past questions with age from 63% to 71% correct was minimal and not significant (Mann-Whitney test: $U(n_1 = 15, n_2 = 17) = 103$, $p = .32$, Cohen's $d = .32$).

Figure 3 shows that Experiment 2 replicates the results of Experiment 1 rather closely: when the second transformation (searching character) is taken counterfactually, children do significantly worse when the character would not have reached the item (21.9% correct; dashed line, conditions 1 and 4) than when he or she would have reached it (81.3% correct; solid line, conditions 2 and 3; Wilcoxon signed ranks test: $Z(N=32) = -4.2$, $p < .01$, Cohen's $d = 1.06$). There were no significant differences between conditions 1 and 4 (Mann-Whitney test: $U(n_1 = 16, n_2 = 16) = 104$, $p = .21$, Cohen's $d = .47$) or conditions 2 and 3 (Mann-Whitney test: $U(n_1 = 16, n_2 = 16) = 128$, $p = 1.0$). Thus, children's errors in condition 1 of Experiment 1 did not result simply from the fact that it was the only condition in which the protagonist cannot reach the item.

The novel part of Experiment 2 was that we also asked children subjunctive past questions that altered the first transformation (where mother put sweets). Response patterns were similar (see Figure 3) and not significantly different from performance on the second transformation (Wilcoxon signed ranks test for first and second transformations: conditions 1 and 4: $Z(N=32) = -1.3$, $p = .20$, Cohen's $d = 0.35$; conditions 2 and 3: $Z(N=32) = 0.0$, $p = 1.0$). Children did significantly worse when the item would have stayed at its initial location (37.5% correct, dashed line, conditions 1 and 4) than when it would have ended up in the character's goal location (81.3% correct, solid line, conditions 2 and 3) (Wilcoxon signed ranks test: $Z(N=32) = -3.3$, $p < .01$, Cohen's $d = 0.71$). Neither conditions 1 and 4 (Mann-Whitney Test: $U(n_1 = 16, n_2 = 16) = 96$, $p = .08$, Cohen's $d = .68$) nor conditions 2 and 3 (Mann-Whitney Test: $U(n_1 = 16, n_2 = 16) = 120$, $p = .63$, Cohen's $d = .17$) showed a significant difference between the number of correct answers for the first or second transformation.

The pattern of answers on our subjunctive past questions allowed us to classify children according to the reasoning strategy that would result in the observed pattern. Table 2 shows the response patterns expected for counterfactual and basic conditional reasoning strategies. Since children did not receive all eight conditions but only two for each transformation, the

table shows which combination of conditions we gave to one group (a) and to the other group (b).

We classified children as *counterfactual reasoners* (CF) if they showed the counterfactual reasoning pattern on all four conditions (two children) or on at least three conditions (four children, allowing one lapse of attention). Four older (23%) and two younger (13%) children showed a counterfactual reasoning strategy. *Basic conditional reasoners* (BC) were those who showed the basic conditional reasoning strategy on all four (11 children) or at least three conditions (one child), which applied to six older (35%) and six younger (40%) children. The binomial probability for inclusion in the CF group is as high as for the BC group: 0.02. An additional four children, two older (12%) and two younger (13%), showed a particular kind of incomplete basic conditional reasoning pattern, which resulted when they switched the person who came to search for the sweets (*searcher switchers*: SS) when the location was counterfactually altered. For example, if the sweets are at L2, the C2 character comes searching for sweets, they end up in C2's room, and we ask children, "Where would the sweets be, if they had not been at L2 but at L1?", children pointed to C1's room. Although this pattern is technically BC (with one very specific lapse, which has a probability of 0.01), we kept it separate because, as we will see, we found the same pattern among some adults who otherwise showed only counterfactual patterns. There were three children, two older (12%) and one younger (7%), whose pattern could be equally correctly classified as counterfactual or basic conditional reasoning (with one lapse of attention, CF/BC, with a probability of .008). Finally, the responses of seven children, three older (18%) and four younger (27%), did not fit any of these response patterns, and we classified them as *nonsystematic* (NS).

Discussion

We replicated the findings that children were much better at answering indicative future questions than subjunctive past questions in Experiment 2. There is clear evidence that children find future hypothetical reasoning much easier than counterfactual reasoning. Another aim of this experiment was to exclude the possibility that children's errors in condition 1 of Experiment 1 occurred because it was the only condition in which the little girl could not have retrieved the sweets from the top shelf. The second experiment reveals that this was not the case. Despite balanced numbers, children still had problems in the conditions (1 and 4) in which basic conditional reasoning leads to a different answer than counterfactual reasoning does.

We also wanted to test alternative reasons for why children had problems in conditions 1 and 4, specifically, difficulty remembering the original location of the item and not looking farther into the past than the counterfactual assumption takes them. If these alternative accounts applied, then children should have found it easier to draw correct conclusions when we made the first transformation counterfactual than when the second was counterfactual. However, this was not the case. Children most likely used basic conditional reasoning rather than counterfactual reasoning.

This conclusion is underlined by the fact that, similar to the results of Experiment 1, at most three of the younger and six of the older children followed a consistent counterfactual reasoning strategy (also counting the CF/BC patterns as counterfactual) when answering subjunctive past questions, whereas eight of the younger and eight of the older children tended to display basic conditional reasoning (also counting the SS group, which showed a one-lapse basic conditional reasoning pattern).

Experiment 3

In particular, the results of the last experiment indicated that even at 6 years, few children, at best 35% (if the ambiguous CF/BC pattern is counted as CF), showed evidence of counterfactual reasoning. We wondered whether adults might be less than perfect on our problems, so in this experiment, we told the stories of Experiment 2 to a group of adults.

Method

Participants—Sixteen adults (seven men, nine women) from ages 14;7 to 75;10 participated in this study. The youngest attended secondary school, nine were university students enrolled in different fields of study, and the remaining six were middle-class employees. They had a mean age of 34;6 with a standard deviation of 16;3.

Procedure—The procedure was exactly the same as in Experiment 2.

Results and Discussion

The adults answered all control, memory, and indicative future questions correctly. Moreover, as Figure 3 shows, they also answered all subjunctive past questions correctly with one exception. When the first transformation (where mother put the sweets) was taken counterfactually, they gave only 81% correct answers, because six people showed the searcher switch (SS) pattern we described for the small group of children in Experiment 2. When the object was counterfactually assumed to have been in a location where the actual character could not reach it, the participants assumed the character who could reach there would eventually come and fetch it.

At first blush, this appears to be a default assumption that four children also tended to make. However, unlike the four children, adults explained that they did not only reason about the fact that, for example, the girl cannot reach the sweets on the top shelf and thus sweets would have stayed there, but they continued to reason that at some later time the boy would come and take the sweets into his room. From these explicit explanations, it seems clear that adults did not engage in basic conditional reasoning that ignored the actual events. Another fact in favor of adults' counterfactual reasoning is that none of them showed the four children's tendency to use basic conditional reasoning when the second transfer was taken counterfactually.

Since we did not elicit explanations from children about their answers, we cannot tell whether they did or did not follow the same strategy as adults. However, the four children also answered with the character's goal locations when the second transformation was counterfactually changed, which adults did not do, so the more parsimonious explanation is that the children showing the SS pattern took a basic conditional approach with the default assumption that the characters tend to bring the goods to their room. This can account for their answer patterns in both cases, when the first and the second transformations were taken counterfactually.

General Discussion

The principal aim of these studies was to get a clearer picture of children's ability to reason counterfactually by controlling for the distinction between counterfactual and other conditional reasoning strategies. With this distinction, we also hoped to shed light on the discrepancy between previous studies' claims about the onset of counterfactual reasoning.

In short, our explanation for this discrepancy is that previous research did not control for children's use of basic conditional reasoning strategies to answer subjunctive questions

about the past. Counterfactual problems seem easy if one can correctly answer them with purely conditional reasoning (e.g., at 3 years, Harris et al., 1996, or 4 years, Riggs et al., 1998). They become very difficult when basic conditional reasoning with plausible default assumptions produces different answers than proper counterfactual reasoning would produce, as this research shows. Indications of that difficulty are also visible in children's understanding of counterfactual emotions like regret or relief (Amsel et al., 2003; Amsel & Smalley, 2000). In order to assess whether children reason counterfactually by following the "nearest possible world" constraint of David Lewis, we used counterfactual problems for which basic conditional reasoning would not produce correct answers. These problems required children and adults to think of what has actually happened and constrain the necessary assumptions for conditional reasoning to the actual events as far as logically possible (known as the nearest possible world). Results show that children, but not adults, tend to follow default assumptions unconstrained by actual events and governed by cognitive availability.

There are, however, competing explanations for results showing discrepancies in the age of onset of counterfactual reasoning. One claim is that children are more likely to engage in counterfactual thinking when the outcome is unwanted or negative (German, 1999; Guttentag & Ferrell, 2004; Roese, 1997). This factor could have contributed to our findings, as children had the hardest time with conditions in which a character reached the desired object, whereas they had an easier time with conditions in which the character failed to reach the desired object (negative outcomes supposedly stimulate counterfactual reasoning). However, as we discussed in the introduction, many earlier studies found that negative outcomes had only minor effects on counterfactual reasoning (Amsel et al., 2003; Amsel & Smalley, 2000) or no advantage at all (Harris, 2000; Kavanaugh & Harris, 2000), so it is unlikely that the massive difference we found in the present study could be due to this possible but minor effect.

Another possible explanation for children's problems with subjunctive past questions is that they have difficulty inhibiting their strong initial responses based on the current reality (Riggs et al., 1998). Beck et al. (in press) found that inhibitory control predicted children's performance on the counterfactual reasoning tasks; in contrast, Robinson and Beck (2000) questioned whether inhibition is a satisfactory explanation, since in many counterfactual reasoning tasks the only error children can plausibly make is to choose the current state of affairs. So, it is unclear whether children do in fact fail to inhibit reality or whether they fail to construct a counterfactual alternative. Robinson and Beck (2000) reasoned further that if children do tend to get trapped in current reality, then it should be easier for them to think of a counterfactual alternative to a *past* reality than to a *current* reality. Children in their study did equally well in both conditions, suggesting that they do not get trapped in current reality. In a similar vein, Riggs et al. (1998) pointed out that inhibitory control cannot account for the difference in performance between counterfactual and future hypothetical reasoning because otherwise children should have problems inhibiting reality in most future hypothetical reasoning tasks as well, since the hypothetically assumed antecedent often differs from known reality, but in fact they do not experience difficulty with future hypotheticals. In any case, in our stories children hardly suffered from realist errors. Their typical errors consisted of answering with another counterfactual location, not with the object's current location. Hence, our results are clearly not the result of weak executive control in inhibiting realist answers.

Working memory limitations, in contrast, might provide a more convincing account for children's failure to engage in counterfactual reasoning. One could argue that children might understand that they should construct a nearest possible world by taking actual events into account but fail to do so because they lack the memory capacity to remember the actual

event, construct the counterfactual scenario, and integrate that counterfactual with the actual event. Beck et al. (in press) tested whether working memory capacity can predict 4-year-old-children's success on counterfactual reasoning tasks. However, the relationship between working memory tasks (Counting and Labelling; Noisy Book) and counterfactual reasoning tasks (causal chains by German & Nichols, 2003; unexpected transfer by Riggs et al., 1998 and false syllogisms) was at most .28. Thus, an overly taxed working memory cannot exclusively—if at all—explain children's difficulties with counterfactual reasoning tasks. Working memory might explain younger children's difficulty with subjunctive past questions when holding two models simultaneously active, but it cannot explain the older children's problems.

Thus, our central finding is that children only gain the ability to reason counterfactually as late as 5 or 6 years. This late onset might also explain why Amsel et al. (2003; Amsel & Smalley, 2000) as well as Guttentag and Ferrell (2004) report such late understanding of counterfactual emotions. We designed our tasks so that in the critical conditions, children could only give correct answers if they naturally adhered to the “nearest possible world” constraint; that is, if they related their conditional reasoning to actual events. This makes it similar to showing counterfactual emotions, except that the direction of the relation is reversed. For instance, regret can be felt only if one compares what one actually received with what one could have received if one had chosen or acted differently. If children up to 6 years or older do not spontaneously compare assumed conditions with actual conditions, then they would perform badly on our tasks and on the counterfactual emotions tasks.

On some other counterfactual tasks (defined by the use of past subjunctive questions), however, much younger children before the age of 5 years perform practically at ceiling (Harris et al., 1996; Riggs et al., 1998). We can explain this by assuming that in these tasks, basic conditional reasoning leads to the same “correct” answers as counterfactual reasoning.

Our suggestion that children give correct answers based on basic conditional reasoning opens up a new venue of explanation. It is related to the idea that with each additional step, it becomes less likely that all of the required default assumptions match the “nearest possible world” criterion. For instance, in the scenarios by Harris et al., the stipulated antecedent “If Carol had taken her shoes off, would the floor be dirty?” triggers fairly directly the relevant knowledge that without shoes, the floors stay clean. In the scenario Riggs et al. (1998, Exp. 1) used, the reasoning is not so straightforward: “If there had been no fire, where would Peter be?” triggers knowledge that without a fire, firemen could be anywhere. However, the story provides children with two possible locations, namely, the ones mentioned in conjunction with Peter: home or post office. With the reality bias diminishing, children will increasingly bring more sophisticated assumptions to bear, for example, that people are more likely to be at home than at the burning post office. Such knowledge would increase “home” responses even though children are still applying basic conditional reasoning.

The findings by Amsel, Trifoni, and Campbell (2005) seem to support this assumption. They compared 6-year-olds, 10-year-olds, and college students' performances on two conditions: (1) *pretend* that in a make-believe world dogs meow and (2) *imagine* what the real world would be like if dogs meowed. Both conditions presented a minor premise, “Rover is a dog,” followed by a question, “Does Rover meow?” The main finding was that 6- and 10-year-old children performed correctly (saying yes) more frequently in the pretend-condition than in the imagine-condition, whereas this difference vanished among college students. The crucial difference is that in the pretend-condition one does not assume that dogs meow in the real world, whereas in the imagine-condition one must assume this, which obviously makes the imagine-condition a counterfactual, as dogs do not meow in reality. It is well known that children perform better on counterfactual syllogism tasks when the counterfactual premise is

framed as pretend (Dias & Harris, 1988; Richards & Sanderson, 1999). This is especially interesting when we consider that the children in our studies found it easier to make background assumptions that were not constrained by reality than to reason with assumptions that were constrained by reality.

The assumption that children use basic conditional reasoning in counterfactual tasks is compatible with a study by Robinson, Rowley, Beck, Carroll, and Apperly (2006), who used a setup in which a mouse went down a slide that split halfway down into a spotted or a striped slide. In one condition, researchers asked the questions when it was still unknown which way the mouse would go (physical possibilities), whereas in the other condition the mouse had already gone into one branch but the child had no knowledge which branch that was (epistemic possibilities). To do the task right children had to put out two mats in order to make sure that the mouse that comes down a slide does not get hurt. A total of 87% of 6-year-olds put both mats out in the physical-possibilities case, but only 43% did so in the epistemic-possibilities case. The epistemic case shares with counterfactual reasoning the need to construct alternative models for an existing state of the world, an ability that seems to emerge around 6 years of age.

Conclusion

We found a large discrepancy in correct answers to past subjunctive questions under two different conditions. When basic conditional reasoning yielded the correct answer, children did much better than when they had to observe the “nearest possible world” constraint—that is, when they had to demonstrate proper counterfactual reasoning. With this discovery and known observations from the literature, we can describe children’s progress on counterfactual reasoning problems that use past subjunctive questions as follows. At 3 years, children still have a noticeable reality bias, but this bias practically disappears by 4.5 years. Children at this age are, however, still not perfect on counterfactual problems because they use basic conditional instead of counterfactual reasoning. The likelihood of a correct answer depends on what general knowledge they can bring to bear on the conditional antecedent presented in the question and how directly it indicates the correct answer, i.e., whether it leads specifically to the correct answer or only contains that answer in a set of options. By 5 or 6 years, some children start to reason counterfactually. They do not leave their reasoning exposed to the vacillations of cognitive accessibility; instead, they understand that it must follow the givens of the actual events as closely as possible (the nearest possible world). Adults’ mastery is close to perfection, at least on our kinds of task. However, one could argue that the few older children who give “counterfactual” answers, instead of using counterfactual reasoning, might have used basic conditional reasoning together with expedient background assumptions—in our study, that the sweets were stored in the top or bottom shelves as a result of where the sweets had actually been stored. This remains a possibility, which future research should clarify. We also leave it to future research to plot the developmental improvements from 6 years to adulthood.

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Figure1.
Structure of Story Worlds in Experiment 1

Figure 2.
Counterfactual reasoning performance on the four different conditions in Experiment 1

Figure 3.
Percent correct answers to counterfactual questions depending on age

Table 1
Expected answers for each reasoning strategy in the four conditions of Experiment 1

<i>Cond.</i>	<i>Actual Events</i>			<i>CF - Change</i>		<i>Reasoning strategy</i>	
	<i>1st Transf.</i>	<i>2nd Transf.</i>	<i>End State</i>	<i>2nd Transf.</i>	<i>CF</i>	<i>BC</i>	
1	L1	C1/2	G1	C1/2 → C2	L1	?(L1, G2) ^a	
2	L1	C2	L1	C2 → C1/2	G1	G1	
3	L2	C1/2	G1	C1/2 → C2	G2	?(L1, G2) ^a	
4	L2	C2	G2	C2 → C1/2	G1	G1	

Note. “x → y” indicates that the real event x was replaced by the counterfactually assumed event y, i.e., “if not x but y had happened.” The original German version for the indicative future question was: “Was passiert mit den Zuckerl wenn jetzt der Simon kommt und nach Zuckerl sucht?” and for the past subjunctive question: “Aber, wenn nicht der Simon sondern die kleine Julia nach Zuckerl gesucht hätte, wo wären denn dann die Zuckerl?”. CF = counterfactual. BC = basic conditional. L1 = sweet is on the top shelf / nut falls into the stone hut. L2 = sweet is on the bottom shelf / nut falls into the wooden hut. C1/2 = boy / dwarf comes along. C2 = girl / squirrel comes along. G1 = boy’s room / dwarf village. G2 = girl’s room / squirrel’s nest.

^aNo prediction about which of the two answers children will give, but they should give the same in both conditions.

Table 2
Expected answers for each reasoning strategy in the eight conditions of Experiment 2

Actual Events											
				CF Change		Reasoning strategy		CF Change		Reasoning strategy	
Cond.	1 st Transf.	2 nd Transf.	End State	1 st Transf.	CF	BC	2 nd Transf.	CF	BC		
1	L1	C1	G1	a	L1 → L2	L2	G1	b	C1 → C2	L1	G2
2	L1	C2	L1	a	L1 → L2	G2	G2	b	C2 → C1	G1	G1
3	L2	C1	L2	b	L2 → L1	G1	G1	a	C1 → C2	G2	G2
4	L2	C2	G2	b	L2 → L1	L1	G2	a	C2 → C1	L2	G1

Note. “x → y” indicates that the real event x was replaced by the counterfactually assumed event y, i.e., “if not x but y had happened.” CF = counterfactual. BC = basic conditional. L1 = sweet is on the top shelf / nut falls into the stone hut. L2 = sweet is on the bottom shelf / nut is on the nut-tree. C1 = boy / squirrel comes along. C2 = girl / dwarf comes along. G1 = boy’s room / dwarf village. G2 = girl’s room / squirrel’s nest.