Children’s Counterfactual Reasoning Strategy in Belief Contravening Problems

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Abstract
In the present study children’s counterfactual reasoning process is examined in belief contravening problems. The first part of this study uses the visual methodology created for adults by Revlin, Calvillo and Ballard (2005). By five, children display similar reasoning strategies as shown in the same task by adults. When confronted with a counterfactual assumption, children resolve the inconsistencies in their beliefs by retaining general statements (“generalist reasoning strategy”). They adopted this generalist strategy equally when the counterfactual assumption assigned new items to a category (“combining problems”) and when the assumption removed an item from its category (“rending problems”). In the second part of the study, a new visual methodology was applied that increases the similarity with the conditions in paper-pencil tasks. Children still display a generalist reasoning tendency, however remarkably less in rending problems. This is more in line with the adult’s counterfactual reasoning tendency in paper-pencil tasks.

Keywords: cognitive development; counterfactual reasoning; belief revision; visual methodology

Introduction
Counterfactual reasoning is defined as “reasoning from false assumptions” (Chisholm, 1946; Rescher, 1964). Revlin, Cate and Rouss (2001) describe counterfactual reasoning as “reasoning that occurs when people are asked to assume for the sake of argument that a fact they previously thought was true is now false and to draw a conclusion on that basis”. A long debate exists about how children acquire causal knowledge, how the ability to reason counterfactually is related to knowledge-acquisition and how counterfactual reasoning is related to Theory of Mind (e.g. Harris, German, & Mills, 1996; Peterson & Bowler, 2000; Sobel, 2004). An important finding is that counterfactual reasoning appears early in life, before children successfully solve false belief tasks (Perner, Sprung & Steinkogler, 2004). For example, the ability to pretend, which develops around the age of two, is an early expression of counterfactual reasoning (Amsel & Smalley, 2000). Pretense, analogous to counterfactual reasoning, starts from an initial premise that is false in reality (e.g., ‘this box is a spaceship’). Around three years of age children are able to produce and reason from different types of counterfactuals spontaneously (Guajardo & Turley-Ames, 2004). Like adults, children generate more (upward) counterfactuals after negative events and generate additive counterfactuals (counterfactuals that add an element to an antecedent) easier than subtractive counterfactuals (counterfactuals that remove an element from an antecedent). Harris, German, & Mills (1996) found that three- and four-year-old children are able to make a distinction between counterfactual antecedents that could have prevented a certain consequence and antecedents that would still have caused a certain consequence.

However, little is known about the transition between the child’s process of counterfactual reasoning and the adult form of belief revisioning. How do we revise our knowledge and beliefs when we are confronted with contradictions? Which beliefs will we revise? This is not only a problem for psychologists, but for cognitive scientists in general. For example, artificial intelligence researchers encounter this problem in developing programs which are able to include new information that is inconsistent with prevailing rules in their data bases (Gardenfors, 1988, as mentioned in Byrne & Walsh, 2005). Should adult reasoning processes be modeled as structurally different from the child’s or do they both rely on the same basic processes?

The purpose of the present study is to examine the development of children’s counterfactual reasoning in belief contravening problems by using a visual procedure created by Revlin et al. (2005) to study adult reasoning. Second, this procedure is altered to increase the similarity to the traditional paper-pencil task and permits the study of children and adults using an identical task.

1 A cognitive theory of counterfactual reasoning in belief revision is proposed by Revlin, Calvillo and Mautone (2003) and Revlin and Calvillo (2008). An important claim of this theory is that the premise’s status, law-like or not, will determine if the premise will be revised or not. The theory is based on David Lewis’ idea of Possible Worlds and shows many similarities with the cognitive theory of pretense proposed by Nichols and Stich (2000).
Belief Contravening Problems

To study the cognitive processes of counterfactual reasoning in belief revision, Rescher (1964) developed the belief contravening problems: a counterfactual assumption creates an inconsistency in our beliefs, which forces us to revise them. The beliefs in these problems are all formulated as categorical (pre-) assumptions; though, most research concerning counterfactual reasoning and belief revision examines the reasoning process with conditional assumptions (e.g., Byrne & Walsh, 2005).

Revlin et al.’s research (2001, 2003 and 2005) concerning counterfactual reasoning is primarily focused on two forms of belief contravening problems: combining and rending. A typical example is shown in problem (1). After certifying the consistency of the three premises, the reasoner is asked to entertain and forth, counterfactual, assumption that introduces an inconsistency into the set of beliefs. Situations such as in (1) are called combining problems because the counterfactual assumption adds a new relation to the set of beliefs (Revlin et al., 2001), which can be arranged as a Modus Tollens argument:

<table>
<thead>
<tr>
<th>(1) Beliefs (pre-assumptions)</th>
<th>Modus Tollens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>general premise</strong></td>
<td>1) All good knights of King William wear a white hat. p(\rightarrow)q 2) This knight here wears a black hat. (\neg q) 3) He works for King Igor. (\neg p)</td>
</tr>
<tr>
<td><strong>particular premise</strong></td>
<td>4) This knight works for King William. p</td>
</tr>
<tr>
<td><strong>counterfactual assumption</strong></td>
<td></td>
</tr>
</tbody>
</table>

In contrast, in rending problems shown in (2), a salient relation that exists is denied (Revlin et al., 2001) or defined differently: the counterfactual assumption denies the outcome of the Modus Pones rule:

<table>
<thead>
<tr>
<th>(2) Beliefs (pre-assumptions)</th>
<th>Modus Pones</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>general premise</strong></td>
<td>1) All heroes wear a white hat. p(\rightarrow)q 2) This figure here is a hero. p 3) He wears a white hat. q</td>
</tr>
<tr>
<td><strong>particular premise</strong></td>
<td>4) This figure wears a black hat. (\neg q)</td>
</tr>
<tr>
<td><strong>counterfactual assumption</strong></td>
<td></td>
</tr>
</tbody>
</table>

To resolve the inconsistency created by the counterfactual premise the general or the particular premise has to be revised. Rejecting the general premise to preserve the particular premise is called the particularist solution (after Revlis, 1974). In contrast, rejecting the particular premise in favor of the general premise is called the generalist solution (after Revlis, 1974).

There are no simple deductive rules that prescribe how to reason from counterfactual assumptions (e.g., Chisholm, 1946). Nonetheless, in paper and pencil tasks\(^2\), college students reliably prefer the generalist solution (Revlin et al., 2001, 2003 and 2005; Revlis, 1974). Their generalist reasoning tendency is more explicit for:

a) combining than for rending problems\(^3\). For rending problems students either do not show a preference for one of the two solutions or they show a preference for the particularist solution (Revlin et al., 2001 and 2003).

b) general statements that express real beliefs (e.g. “All sunflowers are yellow”) than for accidental (arbitrary) generalities (e.g. “All flowers in this garden are red”) (Revlin et al., 2001).

c) beliefs that are a part of an integrated, narrative network.

Hence, if artificial beliefs are integrated in a narrative structure, students treat them in the same way as real, law-like beliefs, as natural semantic categories, and not as arbitrary relations (Revlin et al., 2005).

Parallel to c) is Dias’ and Harris’ finding (1988, as mentioned in Harris & Leevres, 2000) that the way in which premises are presented has an important influence on the cognitive processes of reasoners: counterfactual reasoning of children is enhanced by embedding the assumptions in a fantasy context. In addition, Markovits and Vachon (1989) conclude that presenting counterfactual premises in a fantasy context facilitates young children to accept these premises without interference from their empirical knowledge. Counterfactual reasoning process also improves by instructing children to imagine the counterfactual assumption (Harris & Leevers, 2000).

Concrete, Visual Material

To examine the counterfactual reasoning process of children, who have not yet developed the ability to read, the use of paper-pencil tasks is not suitable.

In 2005, Revlin et al. replaced the paper-pencil tasks by concrete material to examine the effect of visual information on the revision of our beliefs. Each student heard two fantasy stories in total. One story (two kingdoms with battling knights) was attached with a combining problem, the other (a confrontation in a Wild West town between raiders and settlers/heroes) with a rending problem. After hearing a story, college students were confronted with a diorama and a Lego figurine, respectively portraying two locales and a character from the narrative. The experimenter read three story-based assumptions\(^4\) and the students had to confirm the consistency of these assumptions with the diorama and the narrative. Next, the experimenters asked the students to pretend that a ‘counterfactual’ assumption was true (“Let’s pretend that …”), and subsequently if they

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2 Combining and rending problems were offered on paper.
Students had to draw a line through the premise they wanted to reject, to solve the inconsistency.

3 See footnote 1 for a possible explanation of these results.

4 See example in explanation of combing and rending problems.
wanted to change the figurine or to leave it as it was? If a change was made, it was considered as a choice made for the generalist solution, and vice versa for the particularist solution. Results showed a significant preference for the generalist solution (changing the hat’s color), for both combining and rending problems. Revlin et al. (2005, p.13) came to the following conclusion: “The present data suggests that when people are forced to entertain belief-contravening assumptions about objects in the world, they readily relinquish the truth of what we see in favor of an organized abstraction.”

When does this preference of a generalist solution begin? To address this question, the present experiment adopts the standard counterfactual task to allow the study of young children. The subjects are five-, six- and seven-year-old children, instead of college students. Experiment 1 of the present study replicates Revlin et al.’s procedures (2005, Experiment 2) with concrete, visual material to study the counterfactual reasoning of children in belief contravening problems. In Experiment 2 we alter the procedure to increase the similarity to the traditional paper-pencil tasks. This new methodology makes direct contact with the paper-pencil tasks (adult methodology) in ways that other studies do not.

**Experiment 1**

Based on Revlin’s and his colleagues’ research (2005) the type of belief contravening problem has no effect on reasoners’ strategy to resolve inconsistency in their belief system when their beliefs are visually present. In Experiment 1 we examine children’s ability to solve belief contravening problems and their reasoning strategy.

**Method**

The participants were 26 five-year-old children (12 girls and 14 boys, mean age 5:6, range 5:4 to 6:1), 31 six-year-old children (14 girls and 17 boys, mean age 5:10, range 5:3 to 6:3) and 30 seven-year-old children (18 girls and 12 boys, mean age 6:10, range 6:4 to 7:7). All children spoke Dutch as their native language. The two stories from Revlin et al. (2005, Experiment 2), slightly adjusted to children, were used in this experiment. Both narratives were portrayed in diorama’s and PlayMobil figurines. The independent variable was age (three levels, between subjects: five, six and seven years) and the pretense structure (two levels, within subjects: combining and rending problems). The dependent variable was the solution for the counterfactual reasoning tendency for combining and rending problems. Revlin et al.’s visual procedure (2005, Experiment 2; as described above) was replicated. Questions were asked at each point in each story to verify the children’s comprehension of what was being read and to stimulate their attention (e.g. “Do you know what an axe is? Can you point at in the box?”). Independent of whether the children changed the figurine or not, they were asked a question about the meaning of their action (or non-action); this was to check if they understood the implications. Each condition ended with a control-task in which a ‘naked’ (no attributions) PlayMobil figurine was offered. The children were asked to make a good or bad (depending on the condition) person from the figurine. This task made it possible to check the children’s memory of the basic elements in the story and their understanding of the concept of different attributes (sword or axe) and colors (white or black) for the different characters (good or bad).

**Results**

Children, who failed on the control-task and check-question of a certain condition, were excluded from the analysis of that condition. This way the results were corrected for memory and comprehension.

<table>
<thead>
<tr>
<th>Age</th>
<th>Combining</th>
<th>Rending</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>79% (19/24)</td>
<td>94% (15/16)</td>
</tr>
<tr>
<td>6</td>
<td>91% (20/22)</td>
<td>93% (26/28)</td>
</tr>
<tr>
<td>7</td>
<td>81% (22/27)</td>
<td>85% (22/26)</td>
</tr>
</tbody>
</table>

* Numbers behind backslash in table 1 are the total of participants that succeed on the control-task and the check-question.

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5 A pilot study showed that the task was too difficult for four year-old children.

6 A note in Revlin et al. (2005) mentioned “in an independent study, blank trials were included to estimate how often students want to change the Lego figure without there being any implications. Students spontaneously changed the figure less than 5% of the time.”
Discussion
The present findings suggest that the cognitive capacity to reason counterfactually in belief-contravening problems takes place by at least five to six years of age. Furthermore, children demonstrate the same generalist reasoning tendency as college students. This preference to reject a particular belief to preserve a general belief is dominant in both combining and rending problems and for the three age-groups.

The concrete material-procedure as applied in Experiment 1 (and developed by Revlin et. al, 2005) differs from the original paper-pencil-tasks (e.g., Revlin et al., 2001, 2003 and 2005) and raises four important issues. First, the number of response options is different. In the original research the participants had to make a conscious decision between the two explicit solutions (reject one and preserve the other). In the present experiment, there was only one physical change that indicated a generalist strategy, compared to “no change” indicating the Particularist path. It is not clear whether the number of options contributes to the overall effect. Second, there is a saliency issue. In the paper-pencil tasks the general and particular premises were immediately present (both were written down). However, in experiment 1 only the particular premise was constant visual represented, whereas the general premise had to be retrieved from memory. Third, there is the possibility that children have a natural tendency to change things and therefore tended not to leave things as they were (see General Discussion). Fourth, the ‘not changing’ solution was coded as ‘choosing the particularist solution’ while it would be more accurate to code it as ‘not choosing the generalist solution’.

Experiment 2
In Experiment 2 the visual procedure is altered to increase the similarity with original paper-pencil-task. A main alteration is the replacement of the diorama and PlayMobil figurines by drawings. Each premise (pre-assumptions and counterfactual assumptions) and each solution is visually represented by a drawing. Another key modification is that for each solution the participant had to execute an action (replace a drawing). We expect that these procedures will result in a response profile similar to the paper-pencil task and participants will show a decrease in the use of the generalist strategy for rending problems.

We restrict the group of participants (due to organizational difficulties) to seven-year-old children. Experiment 1 didn’t show any significant difference between 5-, 6- and 7-year-olds; however fewer seven-year-old participants were removed from analysis after correction for memory and comprehension.

Method
The participants were 30 seven-year-old children (17 girls and 13 boys, mean age 6:11, range 6:5 to 8:0), all of whom spoke Dutch as their native language. The two stories (and related premises) from Experiment 1 were reused in this experiment. Both narratives were portrayed in drawings. The independent variable was the pretense structure (two levels, within subjects: combining and rending problems). The dependent structure was the solution for the counterfactual problem (general and particular solution). The pretense structure was manipulated within subjects. To avoid order-effects, the order of the two conditions was counterbalanced. In addition, the order in which the two types of solution were offered changed between subjects.

The procedure of this experiment was similar to Experiment 1, with two important alterations. First, the stories were offered without interruptions by comprehension-questions. After hearing the whole story the children were asked to summarize what they had heard. If they could not remember the names of the different characters and/or the respective colors of the hats these characters wore, the missing information was given to them. Second, the three premises were presented one by one. Each premise was supported by a drawing that was placed in front of the participants. After this, the counterfactual assumption was given (“Lets pretend that …”) and the related drawing was placed on top of the drawing that directly contradicted it. Hereby the logic, that was present earlier in the three premises, was now in question. To assure the children understood the implications of the counterfactual assumption, the participants had to explain why the story was no longer correct. If they could not do so, the experimenter repeated the first two premises and mentioned that the ‘pretended’ premise runs counter to these two. Two options were offered as a solution for the counterfactual problem. One option represented the generalist reasoning (e.g. “Either we give this knight a white hat, …”), while the other option represented the particularist reasoning (e.g. “or the knights of King William can also wear a black hat now.”). These options were also visually supported. Each ‘solution’-drawing was placed on the rejected drawing and was described orally. Afterwards the ‘solution’-drawing was placed above that rejected drawing. When the children heard both solutions (and both drawings were placed above the other drawings) they were asked to make a choice. The experimenter emphasized that both options were correct, but that the child had to choose the option that they preferred (“Both of these options are correct, but which one do you find the best?”) and that they had to place the chosen drawing on top of the rejected drawing. To verify if the children understood the implication of their action, they were asked to explain why the story was correct again.

Results
Children, who could not answer one or both of the check-questions, were removed from the analysis of that condition. Results show that 88% (22/26⁸) of the time, seven-year-old children preferred the generalist solution (changed the color

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⁸ Number behind backslash is the total of participants that succeed on the control-task and the check-question.
of hat) in the Combining condition, which differ significantly from chance level ($\chi^2(1)=15.38$, $p<.001$). 70% (19/27) of the seven-year-olds also preferred the generalist solution (changed the identity of the person from hero to thief) in the Rending condition; which also differs significantly from chance level ($\chi^2(1)=4.48$, $p<.05$). Furthermore, the children did not choose significantly more for the generalist path in the Combining condition than in the Rending condition (SR, $N_{non-ties}=7$, $T_{combining}=20$, $p=.188$).

A comparison of the percentage of seven-year-old children preferring the generalist solution in Experiment 1 and Experiment 2 displays a small increase of generalist choices for the combining problems in the second experiment (7%, $p=.245$, $z_{corrected for tied ranks}=-.69$, MWU)$^9$. A more substantial difference is the 15% decrease of generalist choices in the Rending-condition in the second experiment. Although, this decrease is also not reliable ($p=.188$), $z_{corrected for tied ranks}=1.24$, MWU), it is a signal that the altered procedure is more alike to the paper-pencil-tasks. The changed procedure, however, did not have a significant effect on the counterfactual reasoning tendency of seven-year-old children.

**Discussion**

Seven-year-old children show a generalist reasoning tendency for both combining as rending problems. A cross-experimental comparison shows that the altered procedure does not have an effect on the reasoning strategy in combining problems. However, remarkably fewer children prefer the generalist solution for rending problems in Experiment 2. A visual procedure, in which the possible solutions are made explicit and reasoners have to make a conscious choice between these solutions, is more similar to the paper-pencil tasks.

**General Discussion**

The central feature of this study was the comparison of counterfactual reasoning across age groups. Revlin et al. (2005) found that visualization had an effect on the counterfactual reasoning-process of college students in rending problems. In the original paper-pencil tasks college students displayed a generalist reasoning tendency for combining problems, but not for rending problems (e.g. Revlin et al., 2001, 2003, and 2005). When the ‘diorama-figurine’ procedure was used however, students displayed a generalist reasoning tendency not only for combining problems, but also for rending problems. Experiment 1 of this study examined the counterfactual reasoning process of children using a visualization task similar to Revlin et al.’s (2005). Experiment 2 examines children’s reasoning with a visualization task similar to paper-pencil options.

The first experiment of the present study points out how early in childhood the ability to reason counterfactually exists. Children show a ‘mature’ form of counterfactual reasoning around five years of age. Children revise their beliefs by rejecting the particular premise to preserve the general premise, in both combining as rending problems. This is consistent with the student’s results in Revlin et al.’s research (2005), but not with the results of paper-pencil tasks, where the type of belief contravening problem did have an effect on the counterfactual reasoning tendency. We do have to point out that five-year-olds showed a (non-significant) trend to prefer the generalist solution more for rending problems than for combining problems (opposite to effect in paper-pencil tasks). Future research should investigate this trend more thoroughly.

A difference between Experiment 1 and the original paper-pencil tasks is the channel of communication. In Experiment 1 the premises were presented primarily orally and partially visually with PlayMobil figurines. While, the paper-pencil tasks offered all premises on paper. This first raises a concern of a saliency problem. The particular premise, and not the general premise, was visually represented and therefore probably more salient. This problem was absent in the second experiment. A second concern, addressed by future studies, was whether the memory loads on the participants are different in the present rather than the paper and pencil task. This is a pertinent issue because in the present experiment, the experimenter asked children comprehension-questions, which could have drawn their attention to less important information. This way the elements that were needed to solve the counterfactual problem may have lost their importance.

Another limitation of the ‘diorama-figurine’ procedure is that the participants are constrained to choose between doing nothing and changing the figurine. Changing the figurine is coded as ‘revising your beliefs in favor of the general premise’ (rejecting the particular premise to preserve the generalist premise = ‘generalist solution’) and not changing the figurine is coded as ‘revising your beliefs in favor of the particular premise’ (rejecting the general premise to preserve the particular premise = ‘particularist solution’). However, it would be more accurate to code ‘not changing the figurine’ as equal to ‘not choosing the generalist solution’. Note that the single-action choice format in Experiment 1 is especially problematic for children: Nichols and Stich (2000) state that an important difference between imagining and pretending is the pretender’s desire to behave, in a way that is similar to the way some character or object behaves in a real world. Behaving in the ‘diorama-figurine’ procedure is ‘changing the figurine’. Strommen (1973, p. 852) points out, in light of inhibition of a certain action, that “the capacity for self-regulation in simple, repetitive situations may be evident by age 5, but it may nonetheless be unrealistic to expect consistent self-regulation in more demanding situations until age 7 or older”. Because of the foregoing, the generalist solution may have an advantage over the particularist solution in the ‘diorama-figurine’ procedure. These
problems were addressed in Experiments 2 using altered visual procedure (‘drawing’ procedure).

Although for seven-year-olds, the ‘drawing’ procedure does not result in an overall difference in the use of the generalist strategy in comparison with the ‘diorama–figurine’ procedure. The pattern of responding is different: a small increase (7%) of generalist choices was observed in the Combining condition, and a considerable decrease (15%) was observed in the Rending condition. These results are more alike adult reasoning tendency in paper-pencil-task. Thus, the ‘drawing’ procedure seems to have an effect on our belief-revision of rending problems. This has to be confirmed by a future study utilizing the ‘drawing’ procedure to examine adult’s and younger children’s counterfactual reasoning process in belief contravening problems.

Conclusion

The present study examined children’s counterfactual reasoning strategy in belief contravening problems. We used two different visual methodologies that allowed us a comparison across age groups. The first experiment shows that the adult counterfactual reasoning strategy comes early in childhood. At least by five years of age, children prefer the revision of a particular assumption (event) in favor of a general assumption (rule). However, when the different solutions for the counterfactual problems are made explicit (Experiment 2), the type of belief contravening problems has a larger effect on children’s reasoning strategy (at least for seven-year-olds) and corresponds to the strategy shown previously, in paper-pencil-tasks, for adults. The preference for the generalist reasoning strategy is substantially less in rending problems in comparison with combining problems. These findings of an early appearance of counterfactual reasoning suggest the working of a set of fundamental reasoning processes that are upwardly compatible with adult inference making and which may require minimal early experiences to be activated.

References


Acknowledgments

This research was made possible by the financial support from the FWO project No 0320.05 and the Odysseus Type 1 project (Prof. Dr. I. Douven). We would also like to offer our thanks to Prof. Dr. W. Schaeken for his thoughtful comments and corrections to earlier drafts of this paper, to three anonymous reviewers, and to two students, L. Debruyne and S. Steyaert, for their help in the collection of the data described in this paper.

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