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Authors
Schofield, E. Christina
Cheng, Patricia W.

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Sensitivity to Confounding in Causal Inference: From Childhood to Adulthood

E. Christina Schofield (christis@ucla.edu)
Department of Psychology, Box 951563
Los Angeles, CA 90095-1563 USA

Patricia W. Cheng (cheng@psych.ucla.edu)
Department of Psychology, Box 951563
Los Angeles, CA 90095-1563 USA

Abstract

A necessary condition for correctly assessing causality is the absence of confounding causes. This set of experiments assesses whether people are sensitive to confounding when they infer causation. Two stories were constructed, one in which two candidate causes and an outcome perfectly covaried (confounded), and one in which one candidate cause occurred independently of a second candidate cause that perfectly covaried with an outcome (unconfounded). If people reason by forming contrast groups that hold alternative causes constant, then in the confounded case, subjects should say that it is impossible to determine causality when two candidate causes are confounded. In the unconfounded case, subjects should be able to say that the candidate is causal. If people are not sensitive to confounding, then they should attribute causality to both candidates in the confounded case, and the results for the target candidate should be the same as those in the unconfounded case. This experiment was conducted with children and adults. Children saw one of the two conditions, while adults saw both conditions. Both children and adults make a distinction between confounded and unconfounded causes when making attributions of causality. Our results show that children are able to state the indeterminacy of confounded causes at an age much earlier than previously documented.

Introduction

One view of how children learn is that they approach the world as scientists and form theories about the world (e.g. Gelman, 1996) using information about variation and covariation to establish causal connections (Gopnik, Sobel & Schulz, 2001). Further, they intervene upon the world in order to discover these relationships (Schulz, 2003). Although children may have misconceptions in their explanations, as when a child states that he thinks God made the sun out of gold and lit it with fire (Siegler, 1998), the presence of such misconceptions does not mean that children are unable to use the data present in the environment to form correct causal attributions. Given that adults have had many more experiences than children, we should not expect children's theories to be the same as adult's theories, especially for complex phenomena. What is important is whether the same process is utilized when determining causality. In particular, this paper seeks to examine whether both children and adults are sensitive to confounding when there are two candidate causes for a novel outcome.

As well as being a potential means of improving science instruction and for examining whether children assess causality in the same manner as adults, assessing children's sensitivity to confounded causes is also important for differentiating between two models of causal attribution: the unconditional ΔP model (Jenkins & Ward, 1965), and the focal sets approach (Cheng and Novick, 1992).

Under the unconditional ΔP model, people compare the frequency of e, an effect of interest, when c, a potential cause, is present, with the frequency of e when the potential cause is not present:

$$\Delta P = P(e|c) - P(e|{\sim}c)$$

If $\Delta P = 0$, then the candidate is considered noncausal; if ΔP is noticeably greater than 0, then the candidate is thought to cause the outcome, and if ΔP is noticeably less than 0, the candidate is thought to prevent the outcome. In the unconditional version of this model, people ignore confounding and pool over all the information known about the candidate cause. Using this formulation, if both candidate causes perfectly covary with each other and the outcome, then both will be judged as causal. Under the focal sets approach, the same formula can be used, but is evaluated only when comparing across groups where alternative causes are held constant. If people utilize the focal sets approach, they could make a determination when no confounding was present, but would be indeterminate in the case of perfect covariation because no focal set could be formed.

One study looking at third, sixth and ninth graders, as well as non college young adults and undergraduate college students found that before the ninth grade, students were unlikely to state that there was insufficient evidence to determine causality when there is confounding (Kuhn, Amsel, O'Loughlin, 1988). But, these experiments involved causes for which the students were likely to have prior theories, and people interpret ambiguous data in ways that are consistent with their prior beliefs (Darley & Gross, 1983). Kuhn et. al. do not indicate whether students who did not notice the indeterminacy were answering in a manner consistent with their prior theory. Also, this set of studies focuses on the coordination of theory and evidence, and one of criteria used for assessing student's answers was their ability to justify their responses. If this is an unconscious process, students might be sensitive to the differences between conditions, yet unable to justify their responses. In the present study, the task is made much simpler, by presenting the students with a novel effect and asking for their causal attribution without asking for a justification.

Data from two experiments are presented. Both experiments assess whether people differentiate between confounded and unconfounded causes. In one experiment, the subjects are undergraduates, while in the other experiment the subjects are pre-school age children. In both experiments, participants were presented with two possible causes for a novel event, and were asked to determine the cause of the novel event. In one condition the two possible causes were independently occurring, while in the other conditions, the two candidate causes always occur together. If people are sensitive to confounding they should be able to make a causal attribution in the first condition but not the second.

Methods

These experiments were designed to assess the extent to which people are sensitive to the independent occurrence of potential causes of an effect when making judgments of causality. The first experiment was conducted on adults. Even if adults are able to succeed in this task, it could easily be due to prior training. The second experiment was conducted on children. The similar materials were used for both experiments. Below we describe the methods for both experiments before reporting the results.

Experiment 1

Participants 10 undergraduates at the University of California, Los Angles enrolled in the Introduction to Psychology Course participated in the study. Students receive class credit for participating in the study and were recruited using an on-line bulletin board for this course.

Design This experiment had two conditions and utilized a within subjects design. In one condition, the two possible causes of an unusual event were perfectly correlated (confounded). In the other condition, the same two possible causes occurred independently of one another. Subjects were asked about the causality of the candidate causes in turn. The ordering of the stories, as well as the order in which the subject was asked about each candidate cause, was counterbalanced across subjects.

Materials Two passages of approximately the same length were constructed, (one story was 668 words and the other was 681 words). Both passages tell the story of bunny rabbits that went to two different parties.

In both stories, the parties occur at the same time and on the same day. The day of the party, half of the bunnies ate candy. At one of the parties the bunnies ate cake, while at the other party they did not. In the confounded condition all the bunnies who ate candy also ate cake, in the non-confounded condition half of the bunnies who ate candy also ate cake, and vice versa. All the bunnies at the cake party grew new pink wings; none of the bunnies at the "no cake" party did. Two avoid confusion between the two stories, in one story, the bunnies ate green grass candy and yellow cheesecake; in the other story the bunnies ate blue berry candy and orangey orange cake.

At the end of the story, participants were asked about the causality of each of the causal candidates in the story.

1) Does Yellow Cheese Cake/ Blue Berry Cake all by itself make bunnies grow new pink wings? Yes, No, Impossible to tell.
2) Does Green Grass Candy/ Orangey Orange Candy all by itself make bunnies grow new pink wings? Yes, No, Impossible to tell.

The text of the story was accompanied by illustrations, with an appropriately colored wedge in the bunnies' stomachs representing the cake, and a candy shaped object in the bunnies' stomach representing green grass candy.

Because we were attempting to revise the stimuli in order to make the directions clearer for the children, the stimuli underwent slight modification across the 10 subjects. The conditions remained the same, but there were slight changes in wording and pictorial presentation across groups.

The stories were shown as a power point presentation on a 15" computer screen.

Procedure Participants were randomly assigned to conditions that differed based on the ordering of the stories and assessment questions. Participants were then told that they were going to hear a story about bunny rabbits in two little bunny towns; that something interesting was going to happen to these bunny rabbits, and that they were going to try to figure out what happened.

Participants looked at the illustrations on the screen as the experimenter read the story aloud. At the end of the story, participants were asked about the causality of each of the causal candidates in the story.

The experimenter wrote down their answers on an answer sheet as they progressed through the story.

Experiment 2

Participants 16 pre-school children from the Bellagio day care center at the University of California, Los Angeles participated in the study. Nine male and seven female children between the ages of 4;5 and 5;7, with a mean age of 4;11 participated in the study. One student was excluded from the analysis for answering incorrectly on questions about the facts of the stories presented. The rest of the students answered all of the questions correctly (as explained later).

Design This experiment had two conditions and utilized a between subjects design. In one condition, the two possible causes of an unusual event were perfectly correlated (confounded). In the other condition, the two possible causes of an unusual event occurred independently of one another. The order in which children were asked about each candidate cause was counterbalanced across conditions.

Materials The stories presented to the children had the same content as the stories presented to the adults, with two differences. In both conditions, children saw green grass candy and yellow cheesecake. (This was possible because subjects only saw one story, which ruled out the possibility of carryover between stories.) The children's assessment procedure also differed from that of the adults.

Children were first asked for their spontaneous attribution. "Do you think that it is possible to figure out why the bunnies grew new pink wings?". If the child answered yes then the following questions were asked.

1) Why do you think these bunnies [pointing to those who went to the cake party] grew new pink wings?
2) Why do you think these bunnies [pointing to those who went to the no cake party] did not grow new pink wings? The ordering of these two questions was counterbalanced across conditions.

Because children sometimes do not answer in the free response, do not address both of the causal candidates, or do not address the causal candidates in their responses (i.e. "Bunnies grew wings because they wanted to"), additional probes were added, asking about each of the candidate causes separately. Children were told about statements that other children had made while reading this story. Children were asked to say whether they thought these statements were "definitely right, definitely wrong, or impossible to tell." The statements they were asked to judge were

1) GREEN GRASS candy all by itself makes bunnies grow pink wings.
2) YELLOW CHEESE CAKE all by itself makes bunnies grow pink wings.
3) YELLOW CHEESE CAKE and GREEN GRASS candy together make bunnies grow pink wings.

If the child had previously indicated that the yellow cheesecake was causal, they were not asked about the yellow cheesecake again, (and the same for the other candidates).

Procedure Children were randomly assigned to conditions. Children were video taped during the session. In order to accustom children to the camera, they were first introduced to the camera and allowed to see themselves on the LCD screen. Children were then told that they were going to hear a story about bunny rabbits in two little bunny towns; that something interesting was going to happen to these bunny rabbits, and that they were going to try to figure out what happened.

Participants looked at the illustrations on the screen as the experimenter read the story aloud. At the end of the story, children were asked 4 questions to assess whether they understood and remembered the content of the story. The experimenter pointed to a picture of the bunnies with the candy in their tummies and asked "What did these bunnies eat?", the correct answer being candy (or cake and candy in the confounded case). The experimenter then pointed to the bunnies without candy in their tummies and asked "Did these bunnies eat candy?", the correct answer being no. The experimenter then pointed to a picture of the bunnies at the cake party and asked "What did these bunnies eat at the party?" (this question was omitted in the confounded condition if children answered cake and candy to the first question above), the correct answer being cake. The experimenter then pointed to a picture of the bunnies at the no-cake party and asked "Did these bunnies eat cake?", the correct answer being no. Children who did not correctly answer all questions were excluded from the study.

Results

Experiment 1

Adults subjects were sensitive to confounding when they make causal judgments. In the confounded condition, when asked whether cake caused new pink wings, all 10 subjects said it was impossible to tell. When asked whether candy caused new pink wings, all 10 subjects said it was impossible to tell. In the unconfounded condition, when asked whether cake caused new pink wings, 8 subjects said cake did cause pink wings (the correct answer); 1 subject said it was impossible to tell; and 1 subject said cake did not cause pink wings. When asked whether candy caused pink wings, 6 subjects said candy did not cause pink wings (the correct answer); 4 subjects said it was impossible to tell.

Using McNemar's test for 2-related samples of categorical data, we see that the pattern of responses differed across conditions for both of the causal candidates. Subjects were more likely to say the cake was causal in the unconfounded condition than in the confounded condition, and more likely to say it was impossible to assess causality in the confounded condition than in the confounded condition ($p < 0.05$, exact statistic, binomial distribution used). Subjects were more likely to say that the candy was not causal in the unconfounded condition than in the confounded condition, and were more likely to say it was impossible to tell in the confounded condition than in the unconfounded condition ($p < 0.05$, exact statistic, binomial distribution used).

Using a χ^2 for each set of data, we see that subjects are picking the response that corresponds with the focal set theory reliably better than chance in most cases. Each of following χ^2 analyses uses three cells, corresponding to the three possible responses for the task (yes, no , impossible to time). In the confounded condition, subjects all said that it was impossible to tell if the cake was causal ($\chi^2 = 20$, df=2, $p<0.05$) and it was impossible to tell if the candy was causal ($\chi^2 = 20$, df=2, $p<0.05$). In the unconfounded condition, subjects were more likely to say that the cake was causal than any other answer choice ($\chi^2 = 9.8$, df=2, $p<0.05$). None of the subjects said the candy was causal ($X^2 = 10$, df=1, $p<0.05$) and were evenly split between saying the candy was not causal or that there was not enough information to assess the relationship.

Experiment 2

Children were also sensitive to confounding when they make causal judgments, but this data has more variability associated with it than the adult version of the experiment.

Children were categorized into one of five causal attribution categories: the cake is causal, the candy is causal, both causal (jointly or independently), it is impossible to tell, and other causal attribution. If children made a spontaneous causal attribution, this was taken as the value for the measure. Otherwise, the value for this measure was taken from the child answers to questions about each individual candidate.

Using a χ^2 analysis for this data, we see that the pattern of responses differed across conditions, ($\chi^2 = 10.18$, df=4, $p<0.05$). In the confounded condition, 3 children said both were causal and 4 children said it was impossible to tell. No other responses were given by children in the confounded condition. In the unconfounded condition, 4 children said cake was causal, 1 child said candy was causal, 2 children said they both were causal, and one child gave an alternate attribution. No children said that it was impossible to establish causality.

Conclusions

Both children and adults make a distinction between confounded and unconfounded candidate causes when making attributions of causality. All adults said that it was impossible to tell whether the cake or the candy alone caused the wings in the confounded conditions. Because the conditions used in this experiment are consistent with examples used in scientific methodology classes, it is possible that the adults have had prior experience in science classes that train them to be able to do this. The same is not true of the children, however.

The child data suggests that children are able to state that is impossible to attribute causality when two candidate causes perfectly covary at a much earlier age than documented by previous studies. Children as young as 4 years old, less than a third as old as previously believed, made such attributions. They were also able to use frequency data to make a causal attribution.

The difficulty in using data to prove that a theory is correct or incorrect may not be due to student's inattention to confounded causes. Instead, it may be that that having to justify their responses, or an interaction with prior knowledge is the problem. When introducing children to the abstract idea of confounding, it may be useful to build of their intuitions of causal attribution by first having them make judgments of potential causes of novel effects. Their answers to these problems could then be used as a basis for discussion about the abstract concept of confounding.

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