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Do Preschoolers Understand Causality? A Critical Look

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Abstract

While developmental research commonly claims that children have causal understanding, the extent to which such understanding is present is unclear. The current research is a step towards a more conservative look at children's understanding of causality. We test whether preschoolers appreciate the difference between causes and effects, a finding that is commonly taken to show causal understanding in adults. A two-phase blocking paradigm was used in which the causal status of the cues was manipulated to be either potential causes (predictive reasoning) or potential effects (diagnostic reasoning). Results of two experiments show a significant difference between preschool children and adults in that only adults but not children exhibit evidence for differentiation between causes and effects. These results cast doubt on the idea that understanding of causality appears early in development.

Keywords: Cognitive Science; Psychology; Causal reasoning; Cognitive development; Learning; Developmental experimentation.

Introduction

There is a growing body of evidence that even young children have understanding of causality, and that they use this understanding in their thinking about the world (see Sobel, Tenenbaum, & Gopnik, 2004, for a review). Initially, this claim has been limited to single-cue events, such as physical events in which a rolling ball propels a stationary object (Oakes & Cohen, 1990). More recently this claim has been extended to multiple-cue events, events in which children have to pick the causally relevant cue among several cues, all of which are associated to the caused outcome (e.g., Sobel, et al., 2004).

The goal of the current research is to take a more critical look at young children's understanding of causality. Our perspective is motivated by the current debate about the structure of adult causal knowledge (for a review see DeHouwer, & Beckers, 2002). While some researchers claim that adults rely on abstract causal knowledge when solving causal problems (e.g., Cheng, 1997; Waldmann & Holyoak, 1992), others claim that that relatively simple attentional mechanisms can explain adults' performance in such tasks (e.g., Cobos, Lopez, Cano, Almaraz, & Shanks, 2002; Van Hamme & Wasserman, 1994).

Given that adults' causal knowledge is a contested issue, it seems that the presence of causal knowledge in children needs a closer examination. The current study is aimed at placing the findings with children in perspective of the findings with adults. To start, we will briefly describe the developmental evidence of multiple-cue events that was taken to show abstract causal knowledge in children.

A variety of studies have been conducted with a so-called Blicket detector, a machine that lights up when a 'Blicket' is placed on it (e.g., Gopnik & Sobel, 2000; Sobel et al., 2004). Blickets are objects that turn on the lights of the Blicket detector. Children's task is to find the Blicket among other similar looking objects, to make the machine go (or to remove the Blicket to turn the machine off).

An example of events shown to children is presented schematically in Figure 1 (Sobel et al., 2004; Experiment 1). This task is also referred to as a backward blocking task (or screening-off task). A and B refer to the objects presented to children (i.e., the cues), and the outcome O is the response of the Blicket detector (O+: light on; O-: light off). First, cues A and B were placed simultaneously onto the machine and the Blicket detector was activated (O+). Next, cue A was placed onto the machine alone, and the Blicket detector was activated again. The critical question in the test phase pertained to the causal power of cue B. Do children link it with the outcome O+ (because the machine's lights were on when cue B was on the machine during training), or do they understand that cue B, while associated to the outcome O+, is not causally related to it?

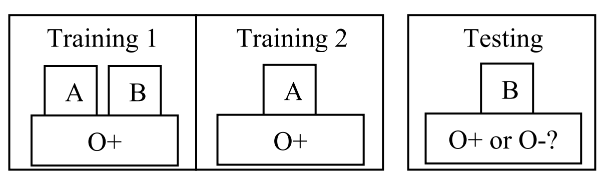

Figure 1: Schematic Procedure of a Backward Blocking Task.

Consistent with the authors' predictions, most 4-year-olds and even some 3-year-olds did not link cue B to the outcome O+. They showed some evidence of *blocking* cue B. However, the difficulty with this (or similar) finding is that blocking per se is not sufficient to show abstract causal knowledge. We explain this next.

Blocking in Animals

Kamin (1969) was the first to demonstrate the phenomenon of blocking in animals. In a crucial experiment, animals were trained in a first phase that cue A (e.g., a light) is paired with an outcome (e.g., food pellet). Upon learning this contingency, cue A was presented simultaneously with cue B (e.g., a tone) and paired again with the outcome. After training, the associative strength was measured of cue B with the outcome. The results show that animals were less likely to expect the outcome when cue B was presented alone.

Similar results were found in a backward blocking paradigm, a task that is similar in structure with the one used with children (see Figure 1) (e.g., Dickinson & Burke, 1996). Apparently, cue B looses its associative strength with the outcome if cue A alone is perfectly associated with the outcome. What seem to be in place are adaptive domain-general learning mechanisms such as learned inattention that allow animals to capture regularities and behave adaptively in a causal environment (cf. Kruschke & Blair, 2000).

These findings undermine a claim that blocking per se is sufficient evidence for abstract knowledge of causality. Blocking could be based on a low-level learning mechanism that allows the learner to disregard cue-outcome relations when the same outcome is caused by another cue. It may be dependent on temporal and other non-causal information, rather than on abstract theories about causal order. Even though children's Blicket task differs from the animal conditioning task in many aspects (e.g., length of training, ecological relevance), it is possible that both tasks require the same theory-free mechanisms. What would be needed as evidence from theory-based causal understanding is a finding in which the learner goes beyond blocking.

Beyond Blocking

Understanding causality includes the ability to appreciate the asymmetry between a cause and an effect. Causes are inherently different from effects, independently of the temporal sequence of events in which a causal relation is acquired. In particular, causes can compete for explaining an effect, whereas effects do not compete for being explained by a cause. As a result, multiple independent effects of a single cause do not attenuate the certainty of inference of a given effect from a given cause. On the other hand, multiple independent causes do attenuate the certainty of inference of a given cause from a given effect because each cause may provide an alternative causal scenario. In other words, an inference from a cause to effect is more certain than an inference from an effect to a cause. This is because one cannot be certain that there are no competing alternative causes, whereas effects do not compete (cf. Pearl, 1988).

To illustrate the certainty of a common cause, take the two cues to be body reactions (e.g., running nose and fever) with each being potentially caused by a virus. Here, presence of the second cue (i.e., fever) does not attenuate the participant's belief that presence of the virus is associated with the first cue (i.e., running nose). Conversely, to illustrate the lack of certainty of a common effect, take the two cues to be two foods (e.g., milk and cereal), with each potentially causing an allergy. Here, given that that the allergy is present, the second (potentially alternative) cause attenuates the certainty that the allergy was caused by the first cause.

Waldmann & Holyoak (1992) tested whether adults appreciate the asymmetry between causes and effects. They used a blocking paradigm similar to the one shown in Figure 1. During training, adults were shown (1) that cue A is linked to outcome O+, and (2) that cues A and B together are also linked to that outcome. After this training, adults had to assess their certainty that cue B alone is linked to outcome O+.

Two conditions were formed that differed only in the cover story of the experiment. In both conditions, the cues were body features of a person (e.g., a person's skin color and weight). In the Prediction condition, these cues were said to be potential causes of the outcome (e.g., they might cause an emotional reaction in others), and after training, participants had to rate their certainty that cue B alone would cause the outcome (common-effect scenario). Conversely, in the Diagnostic condition, cues were said to be potential effects of the outcome (e.g., they might have been caused by a new disease), and after training, participants had to rate their certainty that cue B alone would be an effect of the outcome (common-cause scenario).

The results support the hypothesis that adults appreciate the asymmetry in certainty between cause and effect. They were more likely to block an alternative cause (Prediction condition) than they were to block an alternative effect (Diagnosis condition). It was argued that adults applied different causal models to the same set of associations, and performed differently as a function of them (but see Cobos et al., 2002).

Overview of Experiments

The current set of experiments examined whether children have an appreciation of the asymmetry between causes and effects. The two reported experiments had the same blocking paradigm described above. The schematic illustration of their procedure is shown in Table 1. It consists of two phases: a training phase (Block 1 and Block 2), and a testing phase.

In Block 1 of the training, cue A was consistently linked to outcome O+, while the control cue C was linked to outcome O-, which was explained to participants as "it's impossible to tell whether or not it is linked to the outcome." In Block 2 of the training, cue A was paired with the redundant cue R, both of which were consistently linked to the outcome O, while it was again impossible to tell whether cue C was linked to the outcome (i.e., O-). During the testing phase, participants were asked to determine whether a shown cue is linked to the O+ or O-. Four types of test trials were used, three of which functioned as check trials (they tested whether participants learned the cue-outcome links presented during training) and one of which functioned as critical test trials (it tested participants' inferences about whether cue B is linked to the outcome).

Table 1: Schematic Illustration of the Procedure used in Experiments 1 and 2.

	Cue	Outcome
Training Block 1	A	O+
	C	O-
Training Block 2	A + R	O+
	C	O-
Check trials	A	?
Check trials	C	?
Check trials	A + R	?
Critical test trials	R	?

Note. Three cues were used: A, R (redundant cue) and C (control cue).

As was done in Waldmann and Holyoak (1992), subjects participated in one of two conditions that differed only in the cover story of the experiment. In the Prediction condition, cues were said to be possible causes of the outcome and children's task was to *predict the effect* of a cue. In the Diagnostic condition, cues were said to be possible effects and children's task was to *diagnose the cause* of a cue.

If children appreciate the asymmetry between cause and effect, they should exhibit different patterns of blocking in the Prediction and the Diagnostic conditions. In particular, they should be more likely to exhibit blocking in the Prediction condition, when multiple causes are present, than in the Diagnostic condition, when multiple effects are present.

Two different scenarios were used in the two reported experiments. In Experiment 1, the scenario involved a magical place in which creatures eat special food to turn into something else. The cues are fruits on a plate. In the Prediction conditions, these cues are said to be potential causes (creatures that eat from the plate might turn into a flower), and in the Diagnostic condition, they are said to be potential effects (creatures that ate from an enchanted flower might turn into the plate).

A different was used in Experiment 2. Here, the cues were animal marks found on a forest floor (e.g., a foot print, a hair ball, a bite mark). Again, the status of the cues was manipulated in the cover story. Marks were either potential causes (creatures that see the marks might get scared; Prediction condition) or potential effects (a creature might have left them behind; Diagnostic condition).

Experiment 1

The goal of this experiment was (1) to replicate Waldmann and Holyoak's (1992) findings with a task that can be used with children, and (2) to examine whether young children appreciate the difference between causes and effects. Preschool children and adults were tested in one of two conditions: the Prediction condition and the Diagnostic condition.

Method

Participants Participants were 33 4- and 5-year-olds (16 girls and 17 boys), recruited from suburban middleclass preschools, and 27 introductory psychology students at the Ohio State University, who participated for class credit. Half of the participants in each age group were randomly assigned to the Prediction condition, and the other half were assigned to the Diagnostic condition. The mean age for children was 61.3 months (*SD* = 3.1) in the Prediction condition and 59.6 months (*SD* = 4.9) in the Diagnostic condition. Additional 13 children (8 of which were in the Diagnostic condition) and 3 adults were tested and omitted from the sample because they did not meet the learning criterion (see Procedure).

Materials Cues were realistic pictures of fruits (e.g., apple, orange, strawberry) depicted on a plate. A plate could have one fruit (e.g., cue A) or two fruits (i.e., cues A + R). In the case of one fruit, the plate was partially covered. This was done to aid children in the Diagnostic condition, the condition in which correct performance was to link cue R with the outcome. We reasoned that children in the Diagnostic condition might get confused if the outcome has only one effect (cue A) during the first part of the training, but then has two effects during the second part of training (cue A + R). As a result of this confusion – rather than because of missing causal knowledge – children may block the redundant cue R. For example, they may think cue R could only be an effect of the outcome if it occurs every time the outcome is present. Having a plate partially covered when only one cue is shown avoids this potential confusion. It allows children to reason that cue R was an effect of the cause all along, but was not visible during the first part of the training.

To partially cover the plate, a realistic drawing of a tissue, the size of fruit, was placed on one side of the plate. The cue (fruit) was placed on the other side of the plate.

For children, two laminated cards (2.5 x 2.5 cm) were also used, one being a realistic picture of a plant, and the other one being a stick figure scratching its head underneath a question mark. This second picture was used to explain to children the phrase "impossible to tell."

Procedure Adults were tested in a quiet room on campus, and children were tested in their preschool. The experiment was administered on a computer and controlled by Super-Lab Pro 2.0 software.

The cover story involved Toto, the traveler, who wants to find out about a far-away place. A wizard tells him about some of the things that go on at this far-away place. For participants in the Prediction condition (cue = potential cause), the wizard tells Toto that creatures eat from enchanted plates of fruit and then turn into something else. If creatures eat from some plates of fruit, they will turn into a flower, and if they eat from other plates of fruit, there is no way of knowing what they will turn into[1]. Participants' task was to predict for each plate of fruit whether the creature that eats from it would turn into a flower or whether it is impossible to tell what it would turn into.

For participants in the Diagnostic condition (cue = potential effect), the wizard tells Toto that creatures turn into plates of fruits after they eat from an enchanted food. Before a creature turns into a plate of fruits, it either ate an enchanted flower or it is impossible to tell what it ate. Participants' task is to determine for each plate of fruit whether the creature ate the flower or whether it is impossible to tell what the creature ate.

During a warm-up phase, participants were told that a tissue is sometimes covering part of a plate, and that it is impossible to tell what is underneath the tissue. Several training trials were presented to children until they guessed correctly that it is impossible to tell what's underneath the tissue.

Training and testing stimuli was identical for both conditions. Participants were presented with plates of food, one by one, and asked to determine for each plate whether it is linked to *flower* or to *impossible to tell*. During training, participants were given feedback about whether or not their decision was correct. No feedback was given during testing. In the first training phase (Block 1), plates with cue A (15 trials) and cue C (10 trials) were presented in random order, followed by the second training phase (Block 2) in which plates with cue A + R (5 trials) and cue C (5 trials) were presented in random order[2].

The testing trials followed immediately after the training. They consisted of check trials, those that tested whether participants learned the cue-outcome relations presented during training, and of critical trials, those that tested participants' inferences about the unseen cue-outcome relation. Check trials were plates with cue A (5 trials), cue C (5 trials), and cue A + R (5 trials), and critical trials were plates with cue R (10 trials). All of these trials (check trials and critical trials) were presented in random order. To be included in the sample, participants had to perform correctly on 75% of the check trials. Five children in the Prediction condition and five children in the Diagnostic condition did not meet the criterion.

At the end of the experiment, children were asked to reproduce the story line of the experiment. Particularly, they were asked whether some creatures (1) ate a plate of fruit and then turned into a flower or (2) ate the flower and then turned into a plate of fruit. Each sequence was shown on the computer and children had to choose the correct one. To be included in the sample, children had to perform correctly on this question. While all children in the Prediction condition met this criterion, three children in the Diagnostic condition did not and were excluded from the sample.

Results and Discussion

A preliminary analysis of participants' accuracy during check trials indicated that across conditions, participants were highly accurate, with accuracy ranging from 0.94 to 0.98 for all cells. This shows (1) that both adults and children could learn the cue-outcome relations presented to them during training, and (2) that any difference found between conditions or age group cannot be attributed to differences in learning.

More important was participants' performance during critical test trials, those in which participants had to guess whether the redundant cue (cue R) alone is related to the outcome flower. Recall that a rudimentary understanding of causality shows itself in blocking this cue (i.e., linking it to O- "impossible to tell"). Figure 2 shows the proportion of blocking (i.e., proportion of trials in which a child linked cue R with O-) found for children and adults as a function of condition. A 2 (condition: prediction, diagnostic) by 2 (age group: children, adults) between-subjects ANOVA revealed a significant interaction ($F(1,56) = 6.37$, $p < .02$), with the mean blocking scores differing by condition for adults ($t(25) = 2.53$, $p < .02$) but not for children ($t(31) = 1.06$, $p > .29$).

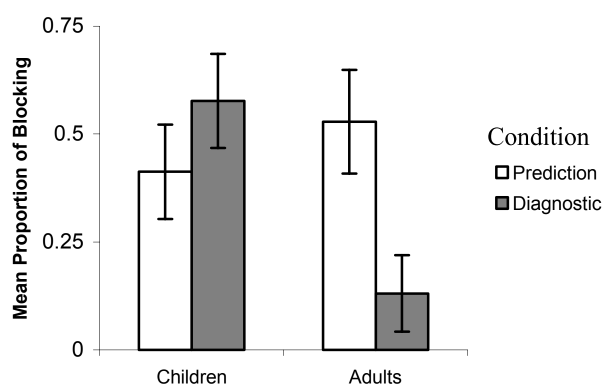

Figure 2: Results of Experiment 1.
Error bars represent standard errors.

These findings point to several important regularities. First, adults show the same dissociation between predictive and diagnostic conditions as documented before. Their

[1] The instructions were given in terms of plates of fruits rather than in terms of fruits by themselves to avoid any possible cues about whether the enchanted food pertains to one fruit or many. If participants believe by mistake that a creature's transformation is caused by the plate rather than by a fruit, they should fail to block the redundant cue R.

[2] Pilot testing established the optimal number of trials, so that children could learn each cue-outcome relation (especially the relation between cue A and the outcome), without loosing interest in the game.

performance in the critical test trials was highly dependent on the cover story. They blocked the redundant cue R in the Prediction condition, when the cue was said to be a cause, but not in the Diagnostic condition, when it was said to be an effect. Finding this dissociation in adult performance indicates that the task is suitable to test abstract causal knowledge in children.

Second, a large majority of children (82%) performed significantly different than would have been expected by chance (binomial probability $p < 0.02$, assuming a chance probability of 0.5). This indicates that they were not simply confused about the task at hand. Also, the standard error obtained for children was virtually identical that the one found for adults, and their degree of blocking the redundant cue R in the Prediction condition was not different from adults' performance in that condition. Taken together, this suggest that children construed the task the same way as adults did, and given that they showed some blocking, they must have construed the task in terms of causal relations rather than as a mere associative learning task.

Finally, and most importantly, children and adults differed in the degree to which they were affected by the predictive vs. diagnostic task context. Even though children could remember the story line at the end of the experiment, their inferences about whether the redundant cue is linked to the outcome was independent of condition. Children blocked the redundant cue, whether it was said to be a possible causes (Prediction condition) or a possible effect (Diagnosis condition).

To ascertain that results of Experiment 1 are not limited to a particular cover story, we conducted Experiment 2, which had the same design and procedure as Experiment 1, but a different cover story.

Experiment 2

Cues were animal marks such as a foot print, a hairball, or a bite mark. In the Diagnostic condition, where the cue is said to be a potential effect, children had to learn whether a particular mark (or marks) was left behind by a creature. We reasoned that children are exposed to animal prints in their everyday environment (e.g., paw prints in the snow) and they may understand that they are made by animals. For comparison, children in the Prediction condition had to learn whether a particular mark (or marks) would scare a creature.

Method

Participants Participants were 25 4- and 5-year-olds (12 girls and 13 boys) randomly assigned to one of the two conditions (Prediction, Diagnostic). The mean age was 60.1 months for children in the Prediction condition and 57.6 months for the Diagnostic condition. Additional 11 children were tested and omitted from the sample because they did not meet the learning criterion (see Procedure).

Materials Cues were colorful drawings of marks that could be made by an animal. They included a print made by a claw, a hairball, a bite mark on a log, and a scratch made by a sharp tooth. As was done in Experiment 1, two laminated cards were used to aid children's responses. One card represented the outcome (a grey amorphous shape with two eyes said to be a creature), and the other represented "impossible to tell" (the same stick figure used for Experiment 1).

Procedure The procedure was similar to the procedure used in Experiment 1 (see Table 1), with differences pertaining (1) to the cover story and materials used, and (2) to the order and number of trials during training and testing.

The cover story involved Toto who wanted to find out about a never-before seen creature, and, for this reason, traveled to the place where this creature lives. He found lots of mark and took pictures of them. In the Diagnostic condition, children were told that the marks were left behind by animals. To explain this phrase, children were shown a picture of a cat's paw print and asked whether it was a bird or a cat that left this mark behind. To ensure that children do not assume that one creature leaves only one mark behind, they were shown four marks simultaneously (a feather, a bird's foot print, a cat's paw print, and a horseshoe). Each mark was explained to them, and they were specifically instructed: "Some animals leave lots of marks behind."

Results and Discussion

During check trials, children did not perform differently as a function of condition. The mean proportion of correct trials was 0.82 (*SE* = .04) in the Prediction condition and 0.89 (*SE* = .04) in the Diagnosis condition.

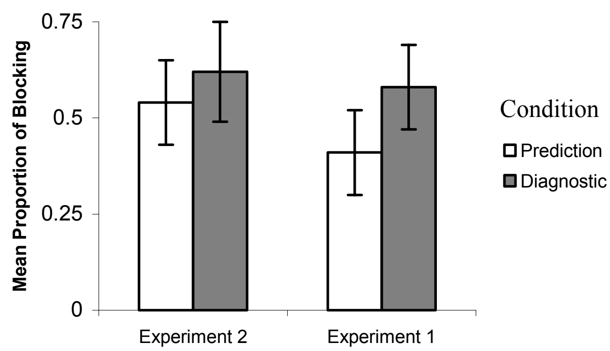

Figure 3: Results of Experiment 2 in comparison with Experiment 1. Error bars represent standard errors.

How did children perform during critical test trials, when asked whether cue R alone is linked to the outcome? Figure 3 shows the mean proportion of blocking by condition. For comparison, results of Experiment 1 are also included in the Figure. As was found in Experiment 1, children's performance did not differ as a function of condition. Despite the simpler task context, children did not reason differently when cues are said to be a potential cause compared to when cues are said to be a potential effect.

It is important to stress that the results are not a mere null-effect. Given that children show considerable amount of blocking of cue R, it is likely that children understood the learned cue-outcome relations in terms of mere associative rather than causal relations. Although they construed the task appropriately, they failed to distinguish between a cause-effect relation and an effect-cause relation. Therefore, the two different contexts used in Experiments 1 and 2 generated essentially the same pattern of results.

General Discussion

Our starting point was to examine whether young children differentiate between causes and effects. One way to examine this differentiation is to present participants with blocking paradigm. If they differentiate between causes and effects, they should exhibit differential blocking in the Predictive and Diagnostic conditions. At the same time, if they do not differentiate between causes and effects, they should exhibit equally strong blocking across the conditions.

Our results clearly indicate that while adults exhibit evidence for differential blocking (and thus understanding of differences between causes and effects), young children exhibited equivalently strong blocking in both the Prediction and diagnostic conditions. Therefore, there is little evidence that young children differentiate between causes and effects.

One could counter argue that children's pattern of results could stem from their difficulty with the Diagnostic condition. Even though the cover story of this condition was largely simplified in Experiment 2, it is still conceivable, that a diagnostic task context puts too high processing demands on children[3]. This is because it requires children to reason "backwards", from effects to causes, rather than from causes to effects. It requires children to ignore the temporal sequence in which events are presented to them (first cue, than outcome), and they need to keep in mind that the outcome happened prior to the cue (e.g., the creature ate the enchanted flower before it turned into the plate of fruit). If true, the argument would suggest that the temporal information is a stronger cue than information about the cause and the effect.

Although this argument would require future research, current findings indicate that in the absence of clear temporal order, young children do not exhibit evidence of differentiating between causes and effects. These results cast doubt on the idea that understanding of causality appears early in development. They suggest instead that it could be a result of learning.

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[3] We thank Michael Waldmann for pointing this out.