

Removing the Time Crutch: Can preschoolers still make causal judgments?

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Abstract

Current theories of cognitive developmental debate the extent to which children's cognition depends on a priori conceptual knowledge. The current set of experiments explores this debate in the domain of causal reasoning: To what degree do preschoolers rely on knowledge about causal relations vs. attention to temporal structure? In three experiments, causal structure and temporal order were either in correspondence or in conflict with each other. Results show a pronounced difference between conditions, with children performing correctly in the correspondence condition, but at chance in the conflict condition. Together, the results suggest that preschoolers' causal judgments depend critically on the co-existence of supporting temporal structure.

Keywords: preschoolers; causal reasoning; attention; conceptual knowledge.

Introduction

Ever since the demise of Piaget's unfavorable view on young children's cognition, developmental research focused a great deal on demonstrating just how competent young children can be. Indeed, even infants seem to know something about the physical world, about causal relations, about theory mind, about numbers, or about language (e.g., see Bremner & Fogel, 2001 for a review). However, the question is still open as to what could account for children's early competence. Is their performance a function of specialized conceptual knowledge that help children constrain an otherwise too complex environment? Or do young children take advantage of general processes of attention and memory that allow them to detect the constraints existent in the immediate context? The current study explores this question in the domain of causal reasoning.

What is the cause?

As perceivers, children are surrounded by cause-effect relations, yet the underlying causal mechanisms are often hidden from view. While the rising sun is likely to cause the rooster to crow, little can be seen about the exact reasons for why this may be so. Often, all there is available are temporal contingencies. On what basis then can children infer causal powers?

One possibility is that children come endowed with an appreciation for causal relations: They might know on a conceptual level that causes and effects exist, they might understand a priori the inherent difference between causes and effects, and they might recognize the importance of causal vs. non-causal correlations. Indeed, preschoolers not only differentiate objects in terms of their causal powers (e.g., Gopnik & Sobel, 2000), they use this knowledge to make inferences, form categories, and learn new words (e.g., Ahn, Gelman, Amsterlaw, Hohenstein & Kalish, 2000; Sobel, Tenenbaum, & Gopnik, 2004).

Unfortunately, this view does not fit well with the current debate about adults' causal knowledge (e.g., see DeHouwer, & Beckers, 2002, for a review). 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 relatively simple attentional mechanisms can explain adults' performance in such tasks (e.g., Van Hamme & Wasserman, 1994; Cobos, Lopez, Cano, Almaraz, & Shanks, 2002). In other words, it is currently not at all clear how to characterize adults' causal judgments.

Given this debate in adult cognition, causal knowledge in children can hardly be a resolved topic. Indeed, when applying methods accepted in the adult literature, young children appear *not* to appreciate the inherent asymmetry between cause and effect (Kloos & Sloutsky, 2005): More specifically, preschoolers do not appreciate that causes can have more than one effect, while effects typically have only one cause. Preschoolers seem to assume instead that a cause has only one effect – same as an effect has only one cause. And this assumption, rather than being specialized conceptual knowledge, follows general attentional biases (e.g., Kruschke & Blair, 2000).

In sum, while some researchers demonstrated sophisticated causal knowledge in young children, others demonstrated that young children fail to distinguish between causes and effects on a conceptual level. If the latter is the case, how do young children manage to perform correctly on causal judgment tasks? What are the primitive attentional processes that young children might take advantage of to make sense of cause-effect scenarios? Or in other words, what is the structure in cause-effect relations that children can understand?

We argue that sophisticated causal knowledge in young children depends on the causal structure being correlated with the temporal order of events. Even infants attend to statistical regularities of events, including the statistical regularities of temporal structure (e.g., Gomez, 2002). It is therefore at least plausible that young children attend to temporal structure to derive causal judgment, rather than invoke conceptual knowledge about cause-effect relations. In other words, seemingly knowledge-rich assumptions about cause-effect relations in young children might reflect primitive processes of statistical learning that take place in the immediate context of the task. The current experiments test this hypothesis explicitly.

Overview of Experiments

We report three experiments with 4- and 5-year-olds to assess the extent to which young children's understanding on causal order depends on the presence of matching temporal order. The general method was to present children with causal relations that are – or are not – supported by temporal order. The crucial test was whether correct performance drops in the second case, when supportive temporal order is missing. Performance in this condition represents the degree to which children's causal judgments are guided by causal knowledge alone.

Experiment 1

A learning experiment was conducted in which 4- and 5-year-olds were presented with causal relations of events. In particular, children learned that pressing button A brought to life creature B, that pressing button C brought to life creature D, and that one of the creatures (e.g., B) bring to life the other creature (e.g., D). Figure 1 shows these causal relations and their temporal order as a function of condition.

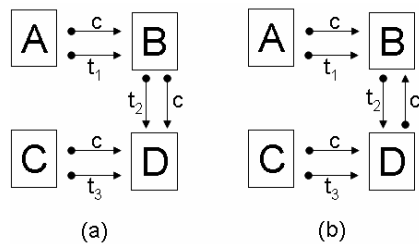


Figure 1: Schematic illustration of a trial set in Exp. 1. A, B, C, and D are events that have causal (c) and temporal (t) order. (a) correspondence condition; (b) conflict condition.

Note that the causal relations $A \rightarrow B$ and $C \rightarrow D$ have corresponding temporal orders (i.e., the cause always preceded the effect), and they are identical between conditions. The crucial manipulation was with the causal relation between creatures B and D. In the *correspondence* condition, this causal relation corresponded with the temporal order (the cause preceded the effect). And in the *conflict* condition, causal and temporal order were pitted against each other (the effect preceded the cause). Children in the correspondence condition were told that creature B

can make creature D, and children in the conflict condition were told that creature B can be made by creature D.

Children's task was to determine the causal power of A vs. C, after having learned each individual relation. If children use causal content to guide their judgment, they should attribute more causal power to A than to C in the correspondence condition (because A causes B, which in turn causes D, while C merely causes D); and vice versa, children should attribute less causal power to A than to C in the conflict condition (because A merely causes B, while C causes D, which in turn causes B).

Method

Participants Thirty 4- and 5-year-olds participated ($M = 61.2$ months, $SD = 2.9$ months, 17 girls and 13 boys), with half of them participating in the correspondence condition (where causal order was supported by temporal order), and half of them participating in the conflict condition (where causal order was pitted against temporal order). One additional child did not meet the learning criterion and therefore was omitted from the sample.

Materials. The cover story involved a character Toto who discovered buttons and creatures on one of his trips to far-away planets. He found out that pressing a button creates a creature, and that some creatures can create other creatures. Toto wants to bring home one of those buttons, but he needs to find the button that could get him two creatures (i.e., the button that would create a creature, which in turn would create another creature). Events A and C corresponded to pressing a colorful button, while events B and D corresponded to the occurrence of a cartoon-like creature. Buttons and creatures had salient features, such that children could easily distinguish among them (e.g., button A was green, and button C was pink). All events were displayed on a computer monitor.

Procedure. All experiments were administered on a computer and controlled by SuperLab Pro 2.0 software.

Children participate in six trial sets, each consisting of a unique set of stimuli. The procedure within a set consisted of training and testing. During training, children were shown that pressing button A makes creature B, that creature B makes (or is made by) creature D (correspondence vs. conflict condition, respectively), and that pressing button C makes creature D. The story was accompanied by corresponding pictures. The three relations were repeated three times. Three check trials followed, presented in random order, to establish whether children correctly learned the three relations. Specifically, two check trials tested children's knowledge about the effects of pressing buttons A and C, respectively, and one check trial tested children's knowledge about which of the two creatures can make (or can be made by) the other creature. Finally, during the crucial test trial, administered at the end of a trial set, children had to pick the button that Toto should take home (the button that would allow Toto to have two creatures).

Results and Discussion

A preliminary analysis pertained to children's performance across check trials. Overall performance was high, with average successful performance across all three check trials in 77% of the six trial sets. There was no difference between conditions, independent-samples $t(28) = 1.5$, $p > 0.14$, with slightly better performance in the conflict condition ($M = 0.81$) than the correspondence condition ($M = 0.72$). Performance on check trials was above chance for both conditions, single-sample $t(14) > 4.7$, $ps < 0.001$, assuming a chance probability of 0.5. Finding that children performed equally well on check trials, even slightly better in the conflict condition, rules out the possibility that the causal content of the conflict condition ("can be made by") was more difficult than that of the correspondence condition ("can make").

How did children perform on critical test trials? To answer this question, we considered only those trials sets for which a child performed correctly across all three check trials. Figure 2 displays children's performance across these trials as a function of condition. An independent-sample t -test revealed a significant difference between conditions, $t(28) = 2.6$, $p < 0.02$, with children in the correspondence condition being markedly more likely to pick the causally correct choice ($M = 0.87$, $SE = 0.06$) than children in the conflict condition ($M = 0.61$, $SE = 0.08$). In fact, children in the latter group did not perform differently from what would be expected by chance, single-sample $t(14) = 1.3$, $p > 0.22$, assuming a chance probability of 0.5.

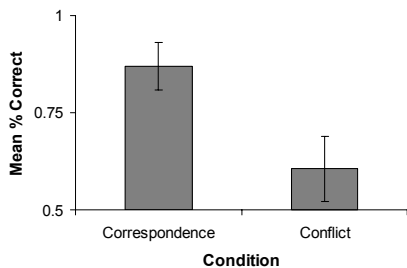


Figure 2: Mean proportion of choosing the causally correct option as a function of condition. Error bars reflect the standard error, and 0.5 is chance performance.

Clearly, preschool children were highly affected by the experimental manipulation. Even though initial learning of the three relations was comparable across the conditions, children's ability to integrate the relations into a causal structure was a function of whether temporal support was present. In the correspondence condition, when the temporal order of events matched that of the causal order, children correctly judged the causal powers of non-adjacent events. But when temporal and causal order were in conflict for one relation (the causal relation between events B and D), children's performance dropped to chance.

Experiment 2

One could argue that children in the conflict condition of Experiment 1 were at a disadvantage compared to children in the correspondence condition because the causal direction switched in the conflict condition from 'make' (e.g., pressing button A makes creature B) to 'made by' (e.g., creature B can be made by creature D). To rule out that this explanation could account for the findings, children in Experiment 2 were presented with only one causal direction, 'make' or 'made by'. Again, causal order was supported by temporal order in the correspondence condition, and it was pitted against it in the conflict condition (see Figure 3). The task was again to determine the causal power of A vs. C.

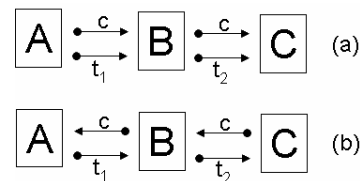


Figure 3: Schematic illustration of a trial set in Exp. 2. A, B, and C are events that have causal (c) and temporal (t) order. (a) correspondence condition; (b) conflict condition.

Method

Participants Thirty-one 4- and 5-year-olds participated ($M = 64.7$ months, $SD = 3$ months, 17 girls and 14 boys), with approximately half of the children in the correspondence condition, and the other children in the conflict condition.

Materials All three events corresponded to the occurrence of a cartoon-like creature, saliently colored and displayed on a computer monitor.

Procedure The cover story involved the character Toto who found funny-looking creatures on one of trips to far-away planets. Toto discovered that some creatures can make other creatures. He would like to take the creatures home, but he can only take one a time. Children's task is to determine which creature Toto should take home. Given a choice between creatures A, B, and C, the causal powers of A vs. C changes as a function of condition. Creature A has more causal power than creature C in the corresponding condition because creature A will make creature B, which in turn will make creature C. Conversely, creature C has more causal power than creature A in the conflict condition because creature C will make creature B, which in turn will make creature A.

As in Experiment 1, children participated in six trial sets, each consisting of a training and a testing phase. During training, children were told (while watching the corresponding creatures) that creature A makes (or is made by) creature B, and that creature B makes (or is made by) creature C (correspondence vs. conflict condition, respectively). These relations were repeated three times, after which children were presented with three check trials.

They had to judge for each creature whether it makes (or is made by) another creature, and if so, which one (or by which one). During the ensuing crucial test trial, children had to pick which of the three creatures Toto should take home.

Results and Discussion

All children passed the three check trials in at least five of the six trial sets with no difference between conditions, independent-sample $t(29) = 0.8, p > 0.8$. Overall, the proportion of trial sets with successful performance across all three check trials was 97%. Note that performance on check trials was higher in this experiment than in Experiment 1, independent-sample $t(59) = 4.2, p < 0.001$, suggesting that our manipulation had successfully decreased the overall difficulty of the task. Any differences between the two experiments in children’s causal judgment therefore reflects the degree to which overall task difficulty mattered.

How did children perform during critical test trials? Figure 4 shows the mean proportion of correct choices, with 0.33 being chance performance. An independent-sample t-test revealed a significant difference between conditions, $t(29) = 3.0, p < 0.005$, with children in the correspondence condition being much more likely to pick the causally appropriate choice ($M = 0.78, SE = 0.09$) than children in the conflict condition ($M = 0.41, SE = 0.08$). Again, children in the latter group did not perform differently than what would be expected by chance, single-sample $t(14) = 0.8, p > 0.39$, assuming a chance probability of 0.33.

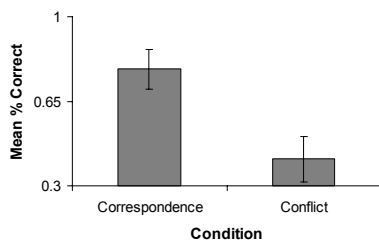


Figure 4: Mean proportion of choosing the causally appropriate option (out of three) as a function of condition. Error bars reflect the standard error, and 0.33 is chance performance.

Overall, the pattern of results replicates the one found in Experiment 1: Children performed significantly better in the correspondence than the conflict condition, with performance in the latter condition being at chance. Despite significantly reducing the degree of task difficulty (as ceiling performance on check trials suggests), children still failed to utilize causal information in the conflict condition, when it was pitted against temporal order.

It is conceivable, however, that children’s drop in performance merely reflects their difficulty with a task context that uses passive voice (e.g., understanding the meaning of ‘being made by’). Rather than failing to utilize the causal structure of relations, children might have been confused about a scenario in which causal order was

described in passive voice. Experiment 3 addresses this concern by using active voice in both conditions.

Experiment 3

Children were presented with a simple causal structure $A \rightarrow B \rightarrow C \rightarrow D$ presented as four binary relations: $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$, and $D \rightarrow E$. For each relation, temporal order matches that of causal order (e.g., the cause A was mentioned before the effect B), eliminating the problem of passive voice. Figure 5 shows the difference between conditions in abstract notation. Depending on condition, the four relations were presented one at a time in one of two orders. In the *ordered* condition, relations followed each other in logical progression (e.g., $A \rightarrow B$ was followed by $B \rightarrow C$). Conversely, in the *random* condition, relations were presented in a random order (e.g., $A \rightarrow B$ was followed by $C \rightarrow D$). While this procedure still dissociates causal from temporal order, children are not faced with passive-voice descriptions of the events.

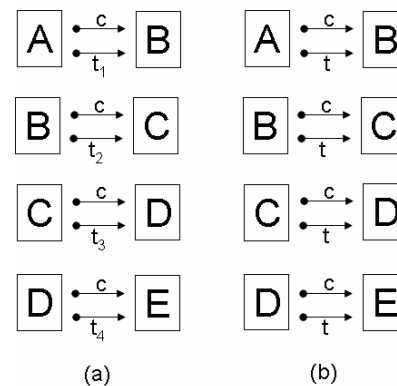


Figure 5: Causal (c) and temporal (t) order of A, B, C, D, E used in Exp. 3. (a) ordered condition; (b) random condition.

Children’s task was to determine the causal power of non-adjacent events (e.g., A vs. C). If children pay attention to the causal relations, independently of the order in which the events take place, they should perform equally well, whether temporal order supports the causal order (ordered condition) or not (random condition).

Of course, there is the possibility that children have inherent difficulty with the logical demands of this task because it requires a transitive inference. To rule out this possibility, two additional conditions were included in this experiment. They used the same ordered vs. random sequences of relations, however the relations were non-causal (e.g., A is better than B) rather than causal. Previous research shows that preschool children can indeed solve transitive inferences if they understand the overarching structure of the relations (cf., Andrews & Halford, 1998; Bryant & Trabasso, 1971; Jager Adams, 1971; Kloos, 2007). This is therefore an ideal paradigm to investigate the degree to which young children appreciate the overarching causal structure of interleaved events.

The resulting 2-by-2 design has the following two factors: temporal structure (ordered vs. random) and content domain (causal vs. non-causal). Comparing performance between

causal and non-causal condition reflects the effect that causal structure has on children's performance. Conversely, comparing performance between the random and ordered conditions reflects the effect of temporal order. Finally, comparing performance between the causal condition with and without temporal support reflects the degree to which children's causal understanding depends on temporal order.

Method

Participants Forty-five 4- and 5-year-olds participated ($M = 59.7$ months, $SD = 4.2$ months, 16 girls and 29 boys), with children about equally distributed among conditions. An additional 21 children were tested ($M = 59.2$ months, $SD = 2.7$ months, 14 girls and 7 boys) and omitted from the sample because of failure to meet the learning criterion (see Procedure). Interestingly, disproportionately more children were omitted from the random conditions ($n = 18$) than from the ordered conditions ($n = 3$).

Materials As in Experiment 2, stimuli (i.e., A, B, C, D, and E) corresponded to unique creatures displayed on a computer monitor.

Procedure The cover story matched that of Experiment 2 as closely as possible: Toto, the traveler, found funny-looking creatures on a far-away planet that he would like to bring home. He could choose between two non-adjacent creatures (i.e., creatures that did not occur together during training). In the causal content domain, children were told that some creatures could create other creatures. Children had to decide which of two (non-adjacent) creatures Toto should take home so that he would have as many creatures as possible. In the non-causal content domain, children were told that some creatures always win against other creatures at tic-tac-toe. Children had to decide which of two (non-adjacent creatures) would win. That would be the creature Toto would like to take home.

The goal of the game (finding the appropriate creature for Toto) was explained to children during an initial familiarization phase. For example, in the non-causal content domain, children were shown that creature A was a better player than the creature B, and that creature B was a better player than creature C. If Toto had to choose between creatures A and C, he would want to take home creature A because that creature would win against creature C.

There was only one trial set during this experiment. It consisted of training with feedback, check trials, and critical test trials. During training, relations were presented in staggered fashion: Children were presented with two relations first (e.g., $A \rightarrow B$, $B \rightarrow C$), then a third relation was added to the two (e.g., $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$), and then the fourth relation was added to the mix (e.g., $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$, $D \rightarrow E$). After each of these training blocks, children were presented with feedback trials (four feedback trials per relation) to provide an additional opportunity for learning. For example, after the first training block, feedback trials

consisted of four AB combinations and four BC combinations, presented in random order.

Check trials followed immediately after training. As before, these trials tested whether children could remember the relation presented to them. There were four check trials per relation, presented in random order with no feedback. Only those children were included in the final sample who responded correctly on at least 11 out of 16 check trials (binomial probability $p < 0.06$, assuming a chance probability of 0.5).

Finally, children were presented with ten critical test trials, two for each of following non-adjacent stimuli combinations: AC, AD, BD, BE, and CE.

Results and Discussion

Figure 6 shows the proportion of correct choices as a function of content domain (causal vs. non-causal relations) and temporal sequence (ordered vs. random sequence). A 2 by 2 between-subject ANOVA revealed a significant interaction, $F(3, 41) = 3.2$, $p < 0.04$, with temporal sequence affecting children's performance in the causal domain, independent-sample $t(21) = 2.1$, $p < 0.05$ ($M_{\text{random}} = 0.51$; $M_{\text{ordered}} = 0.72$), but not in the non-causal domain, independent-sample $t(20) = 0.6$, $p > 0.5$ ($M_{\text{random}} = 0.72$; $M_{\text{ordered}} = 0.77$).

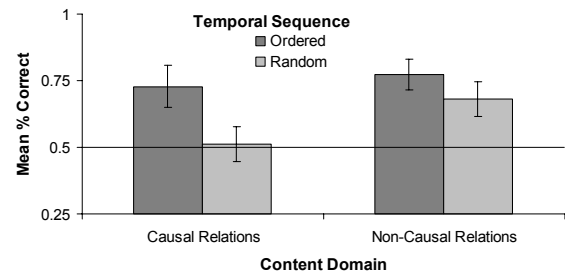


Figure 6: Mean proportion of choosing the causally correct option as a function of condition. Error bars reflect the standard error, and 0.5 is chance performance.

Looking at performance in the random sequence, children could recover the transitive relations above chance in the non-causal condition, single-sample $t(10) = 3.3$, $p < 0.01$, but not in the causal domain, single-sample $t(11) = 0.2$, $p > 0.8$, assuming a chance probability of 0.5. Yet, children could recover the transitive relations in the causal domain when temporal sequence was ordered, single-sample $t(10) = 2.9$, $p < 0.02$.

Above chance performance in the random sequence of non-causal relations rules out the possibility that children had inherent difficulty with the transitive-inference task. And above chance performance in the ordered sequence of causal relations rules out the possibility that children had inherent difficulty with the story line of the causal domain. Finding low performance only in the random sequence of causal relations indicates that children had difficulty with the task only when the causal structure was unsupported by

the temporal sequence. Like in Experiments 1 and 2, appropriate casual judgment depended on supporting temporal structure.

General Discussion

Our question pertained to the extent to which preschoolers' causal reasoning depends on the temporal order in which event are presented to them. Across three experiments, results show a clear pattern: Children performed successfully only when temporal order supported the causal structure, but not when causal events ran counter to the expected temporal order. These findings indicate that children's causal judgments crucially depends on causal structure being supported by temporal structure.

Our findings are in line with a body of evidence that demonstrates the importance of an adaptive, but rather primitive repertoire of attentional processes. Such evidence comes from categorization (e.g., Sloutsky, 2003), language learning (e.g., Samuelson & Smith, 2005), or naïve physics (e.g., Kloos, Silverman & Fenstermaker, 2007). Together, they underscore the claim that young children rely on constraints in the immediate structure of the task context, making sophisticated knowledge, assumptions, and inferences unnecessary for adaptive functioning.

The next step then pertains to the question of development. How do children manage to dissociate causal information from temporal structure without relying on the crutch of time? Clearly even preschool children were not blindly taken by the temporal order. When causal and temporal structure were pitted against each other, children performed at chance, rather than relying solely on temporal order and performing below chance. What does it take to ignore temporal order altogether and selectively attend to causal structure only?

Acknowledgments

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