Preschool Children's Assumptions about Cause and Effect: Temporal Ordering

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Bullock, Merry, and Gelman, Rochel. *Preschool Children's Assumptions about Cause and Effect: Temporal Ordering.* Child Development, 1979, **50**, 89–96. Preschool-aged children have been characterized as lacking an assumption that causes only precede or co-occur with effects. However, when 3–5-year-olds were shown a simple sequence of mechanical events in which 1 potential cause preceded and another followed an effect, they picked the first event as a cause. Further experimental trials indicated that order is dominant over other causal cues. A comparison of nonverbal and verbal responses revealed that, while children as young as 3 years behave as though they use an assumption of unidirectional order in reasoning about causality, it is only the older children who show some ability to articulate this belief.

As adults we assume that causes precede or co-occur with effects; they cannot follow them. Recent investigations suggest that this assumption of the unidirectionality of cause and effect is not shared by preschool-aged children. When Kuhn and Phelps (1976) asked 5½-year-olds to indicate which of two causal sentences described events in a picture, the children responded as though they were indifferent to causal order. For example, they were equally likely to select "The chair gets wet because the water spills" as "The water spills because the chair gets wet" to describe a picture illustrating the first sentence. Shultz and Mendelson (1975) found that 3-year-olds tend to designate the event that follows an effect as the cause of that effect. When a hidden bell rang, young children were more likely to pick as the cause a marble dropped after than before the sound. These findings are consistent with Piaget's (1930) account of young children's understanding of causality. The preschool child is said to associate or "juxtapose" phenomena on the basis of contiguity alone; hence he might well believe that causes follow effects. Despite evidence that supports this characterization of the preschooler's understanding of causality, there are reasons to question its validity.

Kun (Note 1) has argued that the subjects in the Kuhn and Phelps study may not have understood the key connective "because." She suggests the children may have interpreted the word as "and," thus precluding the need to choose one sentence type over the other. To control for this possibility, Kun provided a nonverbal test. She showed 4½–8-year-old children a three-item picture sequence where A caused B and B caused C. For instance: a child pulls a dog's tail (A); the dog bites the child (B); the child cries (C). In the main experimental condition children were asked why B happened and responded by pointing to the A or C picture. Since children at every age showed an overwhelming tendency to select the correct picture, Kun concluded that they applied an order rule to interpret a sequence of psychological cause and effect. Kun's conclusions are supported by Brown and French (1976), who find that after seeing a sequence of causal events preschoolers are capable of reconstructing that sequence of events in a story.

What are we to make of the conflicting characterizations of children's assumptions about causal order presented above? Is the difference only that Kun's (1978) procedure in-

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volved sequences which focused on social attributions, while those of Shultz and Mendelson (1975) and Kuhn and Phelps (1976) did not? We think not. We suggest that the earlier studies have confounded an assessment of the content of a child's knowledge and the structure of his causal beliefs. There are two sources of difficulty for the child. First, it may be that when asked to verbalize a causal relation between unfamiliar events a child cannot help but adopt a recency strategy, as did some of Shultz and Mendelson's subjects, or invoke animistic or phenomenistic explanations, as did Piaget's informants. Children may adopt these strategies either because they lack relevant factual knowledge about the situation or because they cannot integrate the understanding of the new situation with the cognitive demands of verbalizing that understanding. Some support for this idea comes from the finding that young children who are given some experience with an apparatus are more likely to express an understanding of causal relationships between the relevant events (Berzonsky 1971; Mogar 1960; Baillargeon, Note 2; Koslowski, Note 3).

Second, a child may well understand the causal relations between events but lack the verbal knowledge to comprehend or respond to questions designed to tap that understanding. Studies which rely exclusively on verbal procedures may thus confound an understanding of the language used to talk about causation and beliefs about causation.

We sought, then, to investigate the importance of causal order in young children's reasoning about events. We selected a sequence of events that we determined in pilot work could be understood by young children. In addition, we made available a nonverbal expression of a causal judgment about those events.

Picture a long box. A ball rolls down a runway across half the face of the box (event X), disappears, and a second or two later a jack-in-the-box pops out of the end part of the box (event Y). In pilot work we have found that a young child will describe this sequence in causal terms, labeling the first event the cause, the second the effect. However, the cues of temporal order and spatial proximity are confounded here; we do not know if one or both cues were used in the causal inference. To separate these cues, we adopted the logic of the Shultz and Mendelson (1975) design. This was done by placing a second runway on the other side of the jack-in-the-box (see fig. 1). The basic experimental

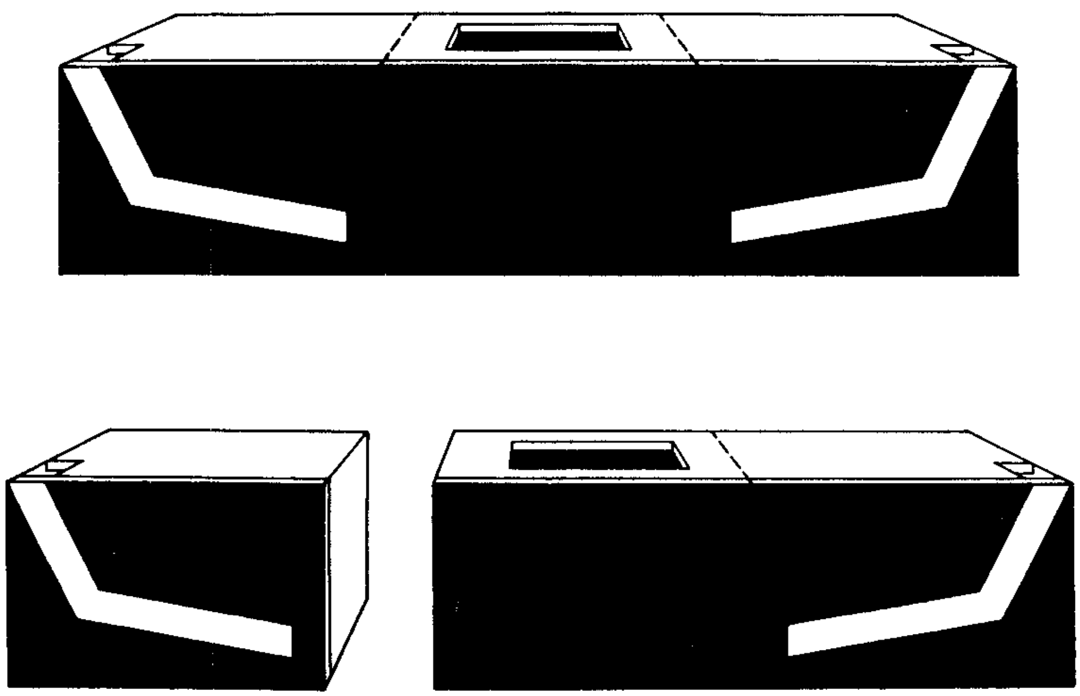

Fig. 1.—Drawings of two views of the apparatus. The top half of the figure shows a child's view during Phases I and II; the bottom half shows the same child's view during Phase III.

condition involved dropping a ball down one runway (event X) before jack jumped (event Y) and a second ball down the other runway after jack jumped (event X′). Note that the events X and X′ differ only with respect to their temporal order relation to the effect of interest. Children who are indifferent to the order cue should make choices at random when asked which ball made jack jump. Children who believe that causes follow their effects should select the second ball (X′). Children who are cognizant of the role of temporal order should select the first ball (X).

Children were asked to point to the runway event which produced the effect; to produce the effect themselves, given one ball; and to answer questions designed to probe their reasons for picking one ball or the other as a cause. These alternative response modes were included to untangle a child's use of assumptions about causation from the articulation of those assumptions. A comparison of the nonverbal and verbal responses may help to clarify whether the responses children made in earlier studies were due to their poor verbal abilities or to the absence of an assumption of unidirectional order in causal sequences.

Method

Subjects

Forty-eight children, including 16 3-year-olds (mean age 3-7, SD 3-1 months), 16 4-year-olds (mean age 4-6, SD 3-7 months), and 16 5-year-olds (mean age 5-3, SD 3-1 months) were tested. The children attended either a YWCA preschool day-care center or a university day-care center, both of which serve a racially and socioeconomically mixed population. Written permission was obtained from parents for each child's participation. The experimenter spent several days in the children's classrooms prior to the experiment, playing with the children individually and in a group. Just before the experimental session, verbal permission was obtained from each child for his or her participation in the study.

Apparatus

Figure 1 illustrates the child's view of the apparatus. Although consisting of three components, the apparatus appears to be one continuous wooden box, 90 cm long, 20 cm high, and 22.5 cm wide, with a shiny black Plexiglas front. On the left and right thirds of the box were two windows showing runways inside the box. The runways began at openings in the top outer corners of the box and dropped sharply at a 75° angle, then continued at a 15° angle for a total of 27 cm. Each runway was a mirror image of the other. The top of the center portion of the apparatus had an 11 × 13 cm opening for a lid, from which a "Snoopy" jack-in-the-box could pop up.

Steel marbles (2 cm diameter) could be dropped down either runway, traversing them at 15 cm/sec. A ball would disappear just before reaching the center portion of the box. The ball was thus visible in the runway for about 2 sec.

The apparatus, from the experimenter's point of view, consisted of three separable boxes which, when adjacent, gave the impression of being continuous. Each of the three wooden boxes was 30 cm long. The runway sections (those on the left and right sides in fig. 1) were constructed so that, after disappearing from view 6 cm before the end of the runway boxes, the balls could silently roll to cups at the rear of the apparatus. A child's causal judgments would thus be based on inferences drawn from what must have occurred after the balls disappeared, rather than on events directly sensed.

The center section of the apparatus housed a commercially made jack-in-the-box, a Snoopy doll, modified so that its action was released through a solenoid switch located inside the box. The switch, in turn, was operated via remote control by a silent radio transmitter (garage door opener) which was concealed under a table and was foot operated. The jack-in-the-box operation and the runway action were thus independent.

Note that, although the apparatus consisted of three independent sections, they could be placed together so that the perception was of balls rolling down runways and into the center jack-box.

Design and Procedure

The procedure consisted of three phases, designed to provide increasing amounts of information about the apparatus. In all phases the standard experimental procedure involved dropping a ball down one runway (event X) before a jack-in-the-box jumped (event Y) and dropping a second ball down the other runway (event X′) after jack jumped.

In the following discussion event X (or X′) refers to a constellation of events: for each instance of the event, a hand puppet associated with side X (or X′) drops a ball, the ball traverses its runway, taking 2 sec, and disappears. Event Y refers to the jack-in-the-box's popping up. We will use a left-right notation to indicate the order of events. Thus, the sequence X→Y→X′ indicates that one puppet dropped its ball and the ball traversed its runway, the jack popped, then the second puppet dropped its ball, which traversed its runway.

The child was introduced to the apparatus prior to Phase I by being shown two hand puppets, each of which spoke in a unique "funny" voice, sat atop one (and only one) of the two runway boxes, and held a steel marble. For any one child, one puppet and runway may be labeled "X," the other runway and puppet "X′." The particular puppet (lion or frog) and particular location (to the left or right of event Y) assigned to events X and X′ were counterbalanced across subjects but consistent within subjects.

Phase I.—The first phase was designed to demonstrate a sequence of events and to assess whether all components of the sequence were noticed and, if so, which component was labeled "cause," which "effect." The X puppet dropped its ball into the X runway, corresponding to its side of the apparatus (note that, while the experimenter operated the puppets, the procedure essentially involved actions by the puppets with questions from the experimenter). The ball traversed its runway (taking 2 sec), disappeared (there was a 2-sec lag), and the jack-in-the-box popped up. Coincident with the start of the jack's action, the second puppet (X′) released a ball into the X′ runway, it traversed the runway toward the center portion (again taking 2 sec), and disappeared.

Children saw the above sequence twice. The experimenter then asked the child, "What happened here?" Following this request for a description, the child saw the X→Y→X′ sequence two more times. On each of these trials, the child was asked to choose the ball that "made jack come up" and provide an explanation. If the child's two choices were the same, Phase I ended. If the two choices were different, Phase I continued for one more trial.

Phase II.—In Phase I children saw a sequence of events and designated cause and effect. Phase II was designed to assess the effect of additional information on a child's causal inferences. The phase began with a choice trial in which the experimenter asked the children to make the jack come up with one ball, choosing between the X or X′ puppet's balls. After the child had dropped a marble and seen the jack come up (either X→Y or X′→Y sequence), he was asked to drop a marble down the other side, and the jack again came up. Children now had seen that sequences X→Y and X′→Y could occur, that is, that both X and X′ could be causes. This manipulation emphasizes that the main difference between events X and X′ in the X→Y→X′ sequence is one of temporal order. Following this demonstration, a causal judgment was requested for the standard X→Y→X′ sequence. A choice of event X as the cause would be stronger evidence in support of the view that young children use order cues, since both events X and X′ could, in principle, lead to the effect.

Phase III.—This phase served to assess the salience of the order cue by pitting it against another cue used to identify a cause, spatial proximity. If young children are reluctant to posit action-at-a-distance, as Lesser (1977) and Koslowski and Snipper (Note 4) suggest, then a violation of spatial proximity cues, but not temporal order cues, might present the child with a conflict over which cue to use. A child with a strong assumption of unidirectional causal order should still pick a first, but spatially removed, event as a cause; a child with a weak assumption or none at all might pick a spatially contiguous but subsequent event as a cause. Thus, to begin Phase III, the experimenter separated puppet X's box from the rest of the apparatus by sliding it 2 inches away. The bottom half of figure 1 illustrates the resulting configuration. The child was asked to predict whether the X puppet's ball would now make the jack come up. Following the prediction, the child saw the standard X→Y→X′ sequence, but with X physically separate from Y and X′. The experimenter asked the child which puppet's ball caused the effect and why. Recall that in this and all previous trials the child had seen the X puppet drop its ball first.

Since it is possible that a child with a weak assumption of the unidirectionality of causal order might in this phase choose event X on the basis of his past choices—that is, a learned association between event X and event Y—a final part of Phase III presented the sequence X′→Y→X. Now the connected X′ is also first. If a child switches from choosing X on an initial trial to X′ on a subsequent trial, we can conclude that correct responses were not based on a learned association between a particular puppet (and its runway and side) and the effect Y.

Phase III continued with parallel pairs of trials at separations of 6 and 12 inches, or until the child indicated that he was fatigued and wished to end the session.

All sessions were tape-recorded for later transcription. The experiment lasted for approximately 20 min.

Results

All children completed the experiment. No effects were found dependent upon the identity of the particular puppets used, whether the first event occurred on the left or right, or which puppet was introduced first. Therefore, these variables are ignored in subsequent analyses.

Phases I and II

Prior to being asked for a causal judgment in Phase I children were asked to describe what had occurred. Fourteen, 12, and 15 of the 3-, 4-, and 5-year-olds mentioned both events X and X′ in their descriptions of the sequences. From this we infer that subsequent choices of event X or X′ in the choice trials are not due to a child's noticing and talking about only a subset of the events of interest.

Phase I choices.—After the two demonstration trials, children had two or three opportunities to make a choice during Phase I, depending on whether their first two choices were consistent.

We used a scoring system similar to that described by Shultz and Mendelson (1975). A choice of event X was given a score of 1; a choice of event X′ was given a score of -1. A choice of both or no choice was given a score of 0. A negative score indicates a judgment that event X′ (the second event in Phase I) was the cause, while a positive score indicates that event X was chosen as the cause. Scores hovering around 0 indicate no consistent choices, as would be predicted if children showed no differential treatment of the causes depending on temporal relations to the effect. Row 1 of table 1 shows the number of children who based their choices on causal order in Phase I. A child was credited with using order if X was chosen at least two of three times (score of .66 or higher). A χ^2 analysis of

TABLE 1

NUMBER OF CHILDREN WHO CHOSE A CAUSE ON THE BASIS OF TEMPORAL ORDER DURING EXPERIMENTAL TRIALS[a]

	Age Group		
Trial Sequence	3 Years	4 Years	5 Years
Phase I.	12	14	16
Phase II.	14	16	16
Phase III, part 1[b]. . .	14	16	14
Phase III, part 2. . . .	12	15	16

[a] Children were classed as choosing on the basis of order if their average score was .66 or higher.

[b] During pt. 1 the sequence demonstrated was $X \rightarrow Y \rightarrow X'$. A correct order response involved choosing event X, which is separated from Y and X′. During pt. 2, the sequence demonstrated was $X' \rightarrow Y \rightarrow X$. A correct order response involved choosing X′. Note that previously X′ has not been an appropriate choice.

Phase I results revealed a reliable tendency for children in all age groups to choose the first event as the cause of the jack-in-the-box's appearance. The respective $\chi^2(1)$ values for the 3-, 4-, and 5-year-old groups were: 4.00, $p < .05$; 9.00, $p < .01$; and 16, $p < .001$. Sixty-seven percent, 83.3%, and 93% of the 3-, 4-, and 5-year-olds chose only the first event in Phase I, while the remaining children represented in table 1 did so at least two of three times. Thus, although the majority of children in all age groups chose the first event, the younger children may have been somewhat less certain of their choices.

Phase II choices.—Phase II began when children were given a ball and asked to make the jack come up. Consistent with their Phase I choices, 10, 14, and 13 of the 3-, 4-, and 5-year-olds put this ball down the X puppet's runway. Again, as in Phase I, we see that 3-year-olds may have been less certain in their choices. After dropping the ball down one runway and seeing the subsequent sequence, children then dropped a second ball down the other runway, thus witnessing both events $X \rightarrow Y$ and $X' \rightarrow Y$. After this demonstration of the efficacy of both X and X′ as causes of Y, children were asked for a causal judgment of the standard $X \rightarrow Y \rightarrow X'$ sequence. Phase II choices are summarized in the second row of table 1. The tendency to choose the X event as cause is reliable for all age groups $\chi^2(1) = 9.0$, 16, and 16 for the 3-, 4-, and 5-year-olds, with all p's $< .01$. Further, 87.5%, 100%, and 93.0% of the 3-, 4-, and 5-year-olds chose only event X when asked to name a cause (i.e., their average scores were 1.00).

Explanations of choices during Phases I and II.—We sorted children's explanations for their choices during Phases I and II into four categories designed to indicate roughly increasing levels of sophistication of causal expression. The categories were (*a*) no explanation, or a response irrelevant to the sequence seen (e.g., "It's got big teeth"); (*b*) explanations which reiterated one element of the sequence, but were not relevant to the experimenter's question of why event X or X′ was chosen over the other (e.g., "Cause popped up"; "Cause ball went"); (*c*) explanations which mentioned two or more elements of the sequence, in order (e.g., "Cause X (or X′) rolls over, then Snoopy comes up"); and (*d*) explanations which outlined an order argument, either explicitly, using order terms (e.g., "It's first"), or implicitly, clearly outlining the full sequence of events (e.g., "When (X) goes, jack comes up, but when (X′) goes jack doesn't come up cause already up"), or speaking of the relation between X and X′ (e.g., "It's because X′ doesn't do anything"). Category *d* also included the ambiguous responses of one 3-year-old and two 4-year-olds. These children used inappropriate relational adjectives (e.g., "louder," "lighter," "stronger"). We scored these responses in category *d* since, although imprecise in their terms, the children did indicate that one event was the cause of Y and one was not because of the relation between the two potential causes. Note that the scoring system is not dependent on which choice a child makes but, rather, on how he or she explains that choice. Interrater reliability for the explanations during these phases was 98%, with disagreements resolved in discussion.

Table 2 shows the number of explanations assigned to each of the four categories.[1] While most children gave responses which fell into the "irrelevant" categories (*a* and *b*), older children tended to talk more about the sequences seen and to posit ways the events might have occurred. Although children could make choices on the basis of an order rule, they were not particularly good at explaining their choices. Level of explanation was not related to choice of event X or X′. It is only with the 5-year-olds that we find at least 50% of the children providing order-based explanations.

Phase III

During the first two phases of the experiment most children picked the first event as a cause for the effect. The children's predictions for whether or not event X would still cause Y to occur when X was separated from Y at the beginning of Phase III (2-inch separation) were mixed: 50%, 38%, and 50% of the 3-, 4-, and 5-year-olds predicted X could not cause Y to occur. Of those who predicted that X could no longer serve as a cause, two-thirds cited the distance between the parts of the apparatus as the reason.

After making predictions, children saw the standard X→Y→X′ sequence, with X separated from Y and X′. Row 3 of table 1 shows the number of children who, after this demonstration, picked the unconnected, first event (X) as a cause. Row 4 of table 1 shows choices af-

TABLE 2

NUMBER OF CHILDREN WHO GAVE DIFFERENT KINDS OF EXPLANATIONS DURING PHASE I AND PHASE II

Category and Summary of Explanation Type*	Phase and Age Group					
	Phase I			Phase II		
	3 Years	4 Years	5 Years	3 Years	4 Years	5 Years
(*a*) None, irrelevant	8	1	1	8	4	2
(*b*) Mention one element of sequence	4	7	2	5	5	2
(*c*) Mention several elements of sequence	2	1	3	2	1	3
(*d*) Order argument	2	7	10	1	6	9

* See text for detailed definitions of categories.

[1] Note that the rank ordering of the categories is by subjective judgment of the authors and is therefore approximate. Categories *a* and *b* are, however, distinctly different from categories *c* and *d*.

ter a demonstration of the sequence X′→Y→X, in which the connected event was first. For children to still be credited as having made a choice based on temporal order, they had to choose the X′ puppet's ball. Since they did, we know that previous choices were not due to a tendency to pick a particular puppet.

In these last two rows of the table we see that most children (of all ages) picked the first event as a cause, regardless of its physical condition (separated or connected) or identity (all $\chi^2(1)$ were $p < .01$). Thus children based their choice on the temporal cues as they occurred on each separate trial.

Phase III explanations.—During Phase III children were asked for two explanations, one for their choice when event X was first but unconnected and one for their choice when event X′ was first and connected. The explanations for the first part of Phase III are similar to explanations for Phases I and II: 3- and 4-year-olds gave responses which were not relevant to the causal questions asked of them, as did half the 5-year-olds. However, when the younger children were asked to talk about the X′→Y→X demonstration during Phase III, they did better. The percentage of younger children who either mentioned order (explanation level *d*) or described the items in sequence and how these items might have acted (explanation level *c*) went to 47%. The 5-year-olds did no better in Phase III than in Phase II. It was as though the separation of temporal and spatial cues served to focus the younger children's attention on the cue of temporal order and thereby encouraged them to talk about it.

Discussion

When one makes a causal judgment about a simple, mechanical event, several cues may be used. The results of this study indicate that preschool-aged children can and do rely on temporal ordering as one such cue. Furthermore, when order is pitted against cues such as spatial proximity, it dominates. While children's choices give clear evidence for an assumption that temporal order is an important causal cue, their explanations lag behind their nonverbal behavior. Older children tended to talk about order; few younger children did. We suspect that this discrepancy between a child's use of temporal order and his articulation of it may account for recent reports of an insensitivity among preschoolers to a causal order rule.

In the first part of Phase III children picked the event which was first, even though it violated another principle of mechanical events: that causes do not act at a distance. One might suppose that the child's tendency to rely on temporal order cues when the first event is separated from the rest of the apparatus reveals yet another belief: that action-at-a-distance applies to mechanical events. With this possibility in mind we reconsidered the protocols for Phase III trials. We coded children's reactions to the Phase III sequences to see whether we could discover an indication that the seeming causal link between two unconnected events (X and Y) was unusual or surprising (see Charlesworth [1969] for a discussion of the inferences one might draw from surprise reactions). We looked at two sorts of data: one from children's predictions for whether the separated X box could cause the effect, and the other from children's reactions to the separated X→Y→X′ sequence. We credited a child with giving an indication of not assuming action-at-a-distance if he did one of the following: (1) predicted separated X box could not cause Y and acted surprised at the X→Y→X′ sequence; (2) predicted separated X box could not cause Y and explained why; (3) when asked to explain a choice of the separated event X, inferred a mechanism, either physical (e.g., "When I wasn't looking the ball slided over") or supernatural (e.g., "It's magic"), or queried the experimenter (e.g., "What! How did that happen?"; "It's a trick, right?"). We found that 50% of the 3-year-olds, 81% of the 4-year-olds, and 68% of the 5-year-olds gave this sort of evidence. Although these data are informal, they suggest that preschoolers do not assume action-at-a-distance, but will tolerate improbable occurrences if they honor a temporal order rule. Recent work by Koslowski and Snipper (Note 4) supports this conclusion.

We return to the question with which we began. How do we explain discrepant accounts of the preschooler's understanding of causality? A comparison of our explanation and choice data highlights one reason: this is that very young children have difficulty expressing their beliefs. When verbalization requirements are removed, as in Kun's (1978) study using picture cards and action-event sequences, or as in the present investigation, using a mechanical sequence of events, even the youngest children tested behaved as though they believed causes occur prior to effects.

Although the Shultz and Mendelson (1975) study minimized the role of verbalizations, their procedure may have involved too limited a set of demonstration trials. Shultz and Mendelson demonstrated their sequence of events two times. We found that our youngest subjects were not as confident about their Phase I choices as they were about their Phase II choices. This suggests that young children need considerable experience with unfamiliar events before they will render confident judgments.

We conclude from this study that children as young as 3 years notice and use temporal order when reasoning about a mechanical sequence of events. They may not articulate their assumptions about this cue or explain why they use it, but it appears to direct their understanding of how events may be causally related. The children in this experiment defined the situation much as we, the adult experimenters (with confirmation from several adult colleagues), did, basing their responses on the temporal relations obtaining between the events they saw. While order is a salient cue, it is not the only cue available to the child. For instance, the spatial relations between events are of concern to the child as well. We find that children find sequences which indicate the operation of action-at-a-distance to be surprising and in need of some explanation. Such reactions are hardly those of a precausal child. Given that they occur, it seems reasonable to suggest that the child's developing understanding of causality derives more from a general ability to understand and explain the content of events than from a shift in assumptions about those cues which are fundamental to an identification of causal relations.

Reference Notes

1. Kun, A. Evidence for a preschooler's understanding of causal direction in extended causal sequences. Paper presented at the meeting of the Society for Research in Child Development, New Orleans, 1977.
2. Baillargeon, R. The young child's conception of physical causality: a new approach. Unpublished manuscript, University of Pennsylvania, 1977.
3. Koslowski, B. Learning about an instance of causation. Unpublished manuscript, Cornell University, 1977.
4. Koslowski, B., & Snipper, A. Learning about an instance of non-mechanical causation. Unpublished manuscript, Cornell University, 1977.

References

Berzonsky, M. The role of familiarity in children's explanations of physical causality. *Child Development*, 1971, **42**, 705–715.

Brown, A., & French, L. Construction and regeneration of logical sequences using causes or consequences as the point of departure. *Child Development*, 1976, **47**, 930–940.

Charlesworth, W. R. The role of surprise in cognitive development. In D. Elkind & J. A. Flavell (Eds.), *Studies in cognitive development*. New York: Oxford University Press, 1969.

Kuhn, D., & Phelps, H. The development of children's comprehension of causal direction. *Child Development*, 1976, **47**, 248–251.

Kun, A. Evidence for preschooler's understanding of causal direction in extended causal sequences. *Child Development*, 1978, **49**, 218–222.

Lesser, H. The growth of perceived causality. *Journal of Genetic Psychology*, 1977, **130**, 143–152.

Mogar, M. Children's causal reasoning about natural phenomena. *Child Development*, 1960, **31**, 59–65.

Piaget, J. *The child's conception of physical causality*. London: Routledge, 1930.

Shultz, T. R., & Mendelson, R. The use of covariation as a principle of causal analysis. *Child Development*, 1975, **46**, 394–399.