# Perception Versus Knowledge of Cause and Effect in Children: When Seeing Is Believing

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*Abstract*

Recent research has shown that even infants have perceptual sensitivity to the causal structure of the world, and it is often claimed that causal knowledge supports many of preschoolers' impressive cognitive achievements. That older children nevertheless can encounter difficulties in causal-reasoning tasks is typically attributed to lack of domain knowledge. A different explanation, however, is that causal structure may appear at more than one level, in perception, as well as in underlying knowledge. Children may make some reasoning errors because they have difficulty coordinating these levels. This article reviews relevant evidence on physical causality: Even infants in their first year perceive the causal structure of simple collision events. This perceptual skill could support rapid causal learning without prior knowledge and thus helps us understand children's precocity—preschoolers already reason with the assumption that causes and effects are linked by underlying physical mechanisms. However, what may promote early development may later become a hindrance: When perception and mechanism point to different causes, children may not realize that mechanism is superordinate. Although the components of competent causal reasoning are available early in development, much experience may be required before children learn how to integrate them.

*Keywords*

perceptual causality; causal mechanism; cognitive development

Causality permeates experience, but typically becomes focal only when something is amiss. The Gestalt psychologist Duncker, for instance, described opening a door at the same moment that a light at the end of the hall came on. He felt his action caused this effect—but also knew this was not true. Simple cues such as temporal contiguity can induce a perceptual impression of causality, but we also reason about the mechanisms linking cause and effect. Duncker's anecdote illustrates that perception and reason can diverge, and also that, in the end, reason wins over perception: Two events cannot be cause and effect without a mechanism by which one produces the other. Whether contiguity is a valid cue, in contrast, depends on the timing of the mechanism under consideration. Without a mechanism, as in this example, contiguity is irrelevant. Why, then, was Duncker subject to this perceptual illusion of causality?

Much research supports the idea that beginning even in infancy, people organize experience in terms of causality. Such causal knowledge is thought to facilitate performance in a variety of cognitive domains (Wellman & Gelman, 1998). Conversely, difficulties in causal reasoning are often attributed to lack of domain knowledge. However, perceptual causality and knowledge of the causal (or generative) mechanism are not always distinguished. In this article, I discuss the changing relation between the two during the course of human development.

## MECHANISM IS NECESSARY FOR CAUSALITY—BUT UNOBSERVABLE

Psychologists of many persuasions have reached some consensus that mechanism is crucial for our naive concept of cause (Bullock, 1985; Cheng, 1993; Schlottmann, 1999; Shultz, 1982; White, 1995). Mechanism is what distinguishes causation from correlation and coincidence. The notion of mechanism is abstract: It is the unobserved, ultimately unobservable "glue" between observed events. Although we may analyze physical systems at progressively finer levels of resolution, none captures mechanism in an absolute sense. We nevertheless need hypotheses about nonobvious features of a system to interpret obvious ones. Their content changes with technological progress and our knowledge about such advances, and we learn to revise specific hypotheses. But unlike Duncker's belief that opening doors cannot turn on lights (a belief people knowledgeable about motion sensors do not share), the belief that some mechanism is necessary for causation is an assumption beyond disproof. If we cannot find a mechanism, we conclude the events are not cause and effect, or that we must search further, but we do not eventually accept causation without mechanism. Even believers in paranormal phenomena do not argue they exist without mechanisms, but merely that these mechanisms are beyond science; nonbelievers deny the phenomena because such mechanisms cannot exist. Mechanism is part of the very definition of cause, with status similar to a logical principle (Bullock, 1985).

Do children reason about unobserved mechanisms linking cause and effect? For Piaget (1937/1954), such reasoning was the end point of development in adolescence. Children's explanations can indeed violate physical constraints ("[God] put a real lot of light bulbs in [the sun]," Siegler, 1998, p. 1), but children lack factual knowledge, not appreciation that there must be a mechanism. Studies of simple systems show this to be the case: When toy cars move in tandem, apparently connected by a wire running through a box, even 4-year-olds open the box to look for it and (correctly) suspect trickery if it is empty (Bullock, 1984). Even when the data are contradictory, children assume a mechanism. Numerous studies show that 4- to 5-year-olds are proficient in considering mechanism, although the evidence is less clear for 3-year-olds.

Not so clear is how the mechanism assumption originates. The classic view is that appreciation of causal necessity begins with feeling the efficacy of our own actions. This direct experience of causal production then gets projected onto external objects. For Piaget, this developmental process involved initial fusion and subsequent slow differentiation of intentional and physical causation. As it turns out, however, confusions between these two kinds of causation are rare, which is evidence against Piaget, though not necessarily against the general view that causal action and causal understanding are linked developmentally. However, a different root of causal understanding may be observation, rather than action.

## SOMETIMES WE SEE CAUSALITY—BUT THIS MAY BE ILLUSION

Recent work has investigated whether infants appreciate causality in events involving agents other than themselves. In Michotte's launch event, one shape moves toward another, which moves upon contact, as in a collision. Adults report they see the first shape set the second in motion. Because they see this even if there is no physical interaction of real objects, this perceptual causality is an illusion. Michotte argued that it arises independently of learning and reasoning, as a property of particular motion configurations. This could provide a perception- rather than action-based foundation for our intuitive idea of cause.

Even infants distinguish contiguous collisions from similar events in which causality is disrupted by a temporal delay or spatial gap. Such findings alone show that babies are sensitive to contiguity, but do not necessarily mean that contiguity signals causality to infants, as it does to adults. However, two independent research groups have disentangled these possibilities. Leslie and Keeble (1987) used a habituation paradigm. They repeatedly showed one group of 7-month-olds a red square launching a green square, until the infants were bored, as indicated by a decrease in their looking time (i.e., habituation). A control group was habituated to a similar noncausal sequence with a pause upon contact. Then, each group saw the old event in reverse (e.g., from right to left, if movement previously had been from left to right). Infants normally react to a perceived change at this point with a recovery of attention (i.e., increased looking times, or dishabituation). Both groups saw the same change in spatiotemporal direction relative to the habituation event, and if this is the only change that they perceived, attention in both groups should have recovered similarly. However, in the causal group, cause and effect were reversed as well, and indeed, infants in this group dishabituated more. Cohen and Oakes later confirmed causal perception at 7 months with a different technique (Oakes, 1994), also showing that the age at which causal perception appears depends on complexity of the display. There is thus converging evidence of infants' sensitivity to causality external to themselves.

Debate about the process underlying perceptual causality continues. Leslie argues that the process is innate. In contrast, Cohen and Oakes see perceptual causality as constructed from experience. Certainly, babies experience collisions, and this may influence their perception, but how can they extract causality if they merely observe successive motions? A standard solution to the puzzle of how structure appears where none was before is to posit that we are "prepared" for learning. In this view, innate biases have evolved for ecologically important stimuli. These biases get learning started and funnel it in an appropriate direction. Innate perceptual causality could provide such a constraint. This does not imply, however, that infants understand cause as adults do. On the contrary, a perceptual shortcut to identifying some causal events is useful precisely because it alleviates the need to reason about what makes these events causal.

## PERCEPTION AS PRECURSOR TO MECHANISM?

Regardless of its origin, once in place perceptual causality could promote rapid acquisition of mechanical knowledge without prior experience. Instances of perceptual causality substantially overlap with cases of real causation, as understood by adults. Thus, causal perception could accelerate early learning by filtering the input for reasoning. Automatic detection of some causal links would help children analyze the structure and directionality of physical systems: Shultz (1982), for instance, studied children's reasoning about invisible links involving light, sound, or wind. One setting showed two fans, one blowing and one off, and a lit candle protected from the active fan by a screen. After 5 s, the second fan was turned on and the shield was moved, so that the first fan extinguished the candle. Even 2- to 4-year-olds tracked these simultaneous changes and determined that the first fan blew out the candle. Their analysis may have been aided by temporal contiguity between the screen's movement and the effect, therefore marking the screen's movement as causally relevant.

Unfortunately, such findings do not demonstrate perceptual causality conclusively, because mechanism considerations, even without perceptual input, yield the same conclusion. Perception and mechanism typically point to the same cause, making it difficult to determine which clue is used in causal reasoning. This overdetermination plagues the wider literature on causal attribution. In the usual paradigm, children choose, say, which of two balls dropped in a box rings a bell, with the mechanism left opaque (a situation analogous to common everyday experiences in which reasoning takes place without definite knowledge of the mechanism). The experimenter then can vary temporal or spatial contiguity between each potential cause and the effect, whether each cause precedes or succeeds the effect, whether the effect is contingent on one of the causes, or whether cause and effect appear similar (loudness of the bell, say, and force of the ball being dropped). Children's attributions in such simple cases do not qualitatively differ from adults'; features like contiguity, succession, contingency, and similarity provide cues to causality for people of all ages. But it is not clear why children use these cues: Choice of a temporally contiguous over a noncontiguous ball, for instance, could reflect concern with mechanism and consideration that whatever is in the box cannot take long to produce the effect. Alternatively, this choice could reflect perceptual causality, rationalized post hoc by a fast mechanism.

## COORDINATING PERCEPTION AND MECHANISM IS DIFFICULT

One recent study suggests that children link contiguity with causality independent of mechanism (Schlottmann, 1999). Children learned about two mechanisms by which a ball dropped into one of two holes at one end of a box could ring a bell at the other end. One mechanism (a seesaw) produced the effect immediately; the other (a runway) took several seconds. The children saw one mechanism placed in the box, but not its location. One ball was dropped in one hole, followed after several seconds by the other ball through the other hole, and then the bell rang immediately. Nine-year-olds knew that with the slow runway, the first ball had to be the cause of the ringing, but with the fast seesaw, the second ball had to be the cause. Younger children often chose the contiguous second ball as the cause in both situations. Their incorrect answers were not due to inability to attend to the first ball or lack of knowledge, nor did the children completely neglect mechanism: Some argued the contiguous ball went slowly, or the runway was accelerated, or appealed to trickery. Instead of discounting the accidental contiguity, children modified their knowledge of the mechanism, trying to make it agree with the perceptual causality.

It appears, then, that young children appreciate the need for mechanism, but do not easily move away from the need for perceptual causality as well. Instead of mechanism-based causality automatically subsuming its precursor, perception and mechanism may be separately co-existing aspects of children's understanding. Integration of the two kinds of causality may take time: In everyday life, in contrast to the laboratory, mechanism is usually a matter of hypothesis, not fact, and perceptually designated causes are not necessarily wrong. Whether we should revise our hypotheses about causality or reinterpret the data is decided on a case-by-case basis, typically from circumstantial knowledge, not direct observation. Conflicts between mechanism and perception, and the principled superiority of mechanism, may not be salient to children.

In this view, perceptual causality plays a dual role, promoting and impeding development for the same reason—that it allows identification of causal events without need to think about why these events are cause and effect. Because there is often (not always) a 1:1 mapping between appearance and mechanism, perceptual causality is useful early in children's development, facilitating learning about systems in which links between components can be directly perceived. When components of such systems are hidden, even young children reason about the structure they cannot perceive any more. However, what is useful early in development may nevertheless later become an obstacle: If perception already provides causality, children may see little need to consider mechanism as well. But both levels must be considered together before children may realize that appearance can mislead if a mechanism operates in an environment contributing accidental features. Bullock (1985) argued that early attention to perceptual contiguity, because of its ecological validity, implicitly involves mechanism. However, the link between such early implicit and later explicit understanding seems indirect and can produce paradoxical effects.

The distinction between underlying mechanism and perceptual appearance may seem elusive. Phenomenally, we often fuse the two, taking characteristic appearance to show "what the mechanism looks like." However, features of appearance are merely probabilistic pointers to mechanism; they may or may not be direct manifestations as well. The distinction helps clarify contrasts between competent performance of infants and inept performance of older children in tasks involving similar mechanisms: Infants succeed when salient cues are relevant and underlying principles can remain implicit in the reaction to appearance. Without salient cues, children need explicit mechanism knowledge to select valid, if more subtle, surface features. But when salient cues are irrelevant, children must additionally inhibit their reaction to surface appearance. This demands considerable control over processing (so-called executive control), requiring knowledge not only of the underlying mechanism, but also that appearance can mislead.

Future research will consider the coordination of perceptual and mechanism-based causality in more detail, as there are also implications for education: We foster learners' intuitive understanding through examples with characteristic surface structure. However, generalization beyond intuitive cases is often difficult—perhaps because learners, unaware that appearance need not reflect mechanism directly, fail to decrease their reliance on obvious features even if those features do not fit with their knowledge of the underlying mechanism.

The studies cited all involved mechanical systems, but underlying structure and appearance provide separable constraints on cognition in many other domains. Research on biological kinds and on naive psychology (theory of mind) has also shown preschoolers' impressive ability to consider structure not obvious in appearance (Wellman & Gelman, 1998). On the one hand, there may be perceptual precursors to understanding psychological causality in infancy (Schlottmann & Surian, 1999). On the other hand, Keil (1989) reported that older children made errors regarding biological kind when an animal had misleading appearance. His findings are consistent with the argument here in that these errors depended on children's understanding of how the appearance came about: Children could discount it if it was created through disguise, but were misled if it was created through medical intervention. The present view—that young children pay attention to both apparent and underlying structure, but cannot always integrate these two until later in development—could apply more widely than to reasoning about mechanical causality alone.

## NOT SEPARATE, BUT SEPARABLE PROCESSES

How do the perceptual and mechanism views on causality in the developmental literature contrast with the "Humean" perspective dominant for adults? Hume argued that we learn to take events as cause and effect only if we see them co-occurring repeatedly. Modern versions of this view hold that an event is considered a cause if it predicts the effect well; to determine whether it does, we compute event statistics over multiple occurrences. Perceptual causality, which may occur on first exposure without requiring prior experience with the events, is either considered an exception to the statistical approach (Dickinson & Shanks, 1995) or is assumed to occur because the single encounter is parsed into multiple event segments to make statistical analysis possible (Cheng, 1993). Either way, children are sensitive to complex contingencies in their actions, but their judgment reflects event contingencies only in simple circumstances.

Conceptually, observed contingency, like contiguity, can mislead. Thus, recent statistical approaches acknowledge that the consideration of mechanism safeguards us against inferring causality from spurious correlation, as it safeguards us against perceptual illusion. Causal predictive relations emerge from the data only if events connected by appropriate mechanisms are selected for statistical analysis. This requires some prior knowledge of the causal mechanism—and yet the statistical strategy is needed to discover relations generated by unknown mechanisms. To solve this conundrum, Cheng proposed that prior knowledge about alternative mechanisms provides the necessary constraint. Ultimately, this approach requires some innate constraints—like perceptual causality—to enable statistical analysis. Thus, the three approaches become complementary.

Because mechanism-, statistical- and perception-based analyses are usually redundant, pointing to the same causes, it is tempting to treat one approach as subsuming the others. Conceptually, mechanism is superordinate, and adults' reasoning can reflect this (Ahn, Kalish, Medin, & Gelman, 1995), but normally we do not clearly distinguish between the different forms of analysis. In this article, I have argued that the underlying processes may nevertheless be separable in development. Separability of the processes could be advantageous for adults as well as for children: Causal reasoning is a means for learning, but in the real world we have no guarantee that the answers our reasoning produces are correct. If we always relied on perceptual or statistical strategies, we would go down various blind alleys, but if we always relied on mechanism we would be locked into prejudice, having no way to go beyond what we already knew. It may be the tension of partially independent processes that allows flexible adaptation to changing circumstances.

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