

The Development of Children's Causal Explanations

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A fundamental task for all humans is explaining why things happen. Research on conceptual development indicates that even children as young as 3 years of age can use knowledge of cause and effect relationships to make predictions (Shultz, 1982), engage in efficacious interventions (Kushnir & Gopnik, 2007; Schulz & Gopnik, 2004), and provide explanations for phenomena in the world (Legare, Wellman, & Gelman, 2009; Wellman, Hickling, & Schult, 1997). Not only do young children frequently seek explanations by asking questions (Callanan & Oakes, 1992; Chouinard, 2007; Hickling & Wellman, 2001), they also construct their own explanations (Legare, 2012; Legare & Gelman, 2014; Legare, Gelman, & Wellman, 2010).

However, other research (e.g., concerning children's metacognition) has shown that young children are surprisingly poor at assessing their own understanding and that this ability develops dramatically across development. Indeed, both adults and children overestimate the detail and depth of their explanatory knowledge (Mills & Keil, 2004; Wilson & Keil, 1998). Taken together, these two sets of findings produce something of a paradox in the literature on children's causal reasoning. On the one hand, children are active explanation-seekers and readily seek out and provide causal explanations. On the other hand, they seem to be poor at assessing their own causal knowledge and often think they understand things when they do not. What then motivates children to ask questions and generate explanations if the result of this process is often children concluding that they understand something when they do not? More specifically, what kinds of events do children feel most compelled to explain?

Children readily make use of covariation information, statistical regularities, and causal relationships in order to understand causal outcomes, frequently from very limited available input (Gopnik, Sobel, Schulz, & Glymour, 2001; Schulz & Gopnik, 2004; Kushnir & Gopnik, 2007). If children have a cognitive model of the world based on a framework of anticipatory causal regularities, they would be well-equipped to rapidly form expectations contingent upon prior beliefs or knowledge. Given a predisposition to forecast causal regularities, children may anticipate that *outcomes will continue to occur as expected* and find consistent outcomes especially worthy of explanation. Constructing explanations for events that are consistent with children's prior knowledge and experience may indeed be an important function of children's own explanations. For example, explaining consistent outcomes may provide children with an important opportunity to deepen their understanding of causal phenomena by allowing them to generate causal mechanisms.

Another intriguing possibility is that explanation is motivated by discovery (Legare, 2014). That is, young children might especially value, seek, and provide explanations for events that are inconsistent with their current expectations. According to this possibility, because children readily form expectations for causal regularities based on prior knowledge (even when sparse), children may be highly motivated to attend to irregular or discordant information. Information that is inconsistent with how they expect things to happen could be especially informative and noteworthy because it indicates that their prior knowledge about a causal relationship or outcome was incomplete or inaccurate. Therefore, children may be vigilantly attentive to and more likely to attempt to explain disconfirmatory outcomes. If this were the case, engaging in explanation

would allow children the opportunity to accommodate and reconcile inconsistent information in the context of prior beliefs. Forming explanations for inconsistent outcomes may provide children with the opportunity to generate new hypotheses regarding events that seem to disconfirm their prior knowledge (Legare, et al., 2010; Legare, 2012; 2014).

Before addressing the question of how these two competing hypotheses about the function of children's explanations have been tested, we will present an overview of the developmental literature on causal explanatory reasoning, followed by a discussion of the role of contrastive outcomes in shaping causal explanation, and an overview of the kinds of events that provoke or trigger causal explanation.

The development of causal reasoning: The role of explanation

The development of causal reasoning has been an important topic in developmental psychology since Piaget (1929), and children's causal reasoning has received renewed attention in more recent years (Gopnik & Schulz, 2007), especially from those characterizing children's knowledge in terms of naïve theories (Carey, 1985; Gopnik & Meltzoff, 1997; Gopnik & Wellman, 1994; Keil, 1989; Wellman & Gelman, 1998). A substantial amount of developmental research has demonstrated that young children understand many general causal principles (Bullock, Gelman, & Baillargeon, 1982; Kushnir & Gopnik, 2005; Schulz & Gopnik, 2004; Shultz, 1982) and possess rich causal knowledge (Wellman & Gelman, 1998). However, less is known about how causal reasoning develops and the role explanation plays in this process.

A central function of causal reasoning is to provide explanations for phenomena in the world. Causal explanations play a central role in both everyday reasoning (Gopnik,

2000; Hickling & Wellman, 2001; Hilton, 1988; Keil, 2006; Keil & Wilson, 2000; Sloman, 2005) and scientific theories (Hempel, 1965; Pitt, 1988; Salmon, 1984, 1989; Strevens, 2006; Trout, 2002, 2007; Woodward, 2003). Additionally, prominent theories of conceptual development (Carey, 1985; Keil, 1995, 2003) and category learning (Murphy, 2002; Murphy & Allopenna, 1994) assign a central role to causal-explanatory understanding, claiming that explanation is central to the nature and development of naïve theories (Wellman, 1990) and concepts (Murphy & Medin, 1985). Indeed, the explanatory component of children's developing knowledge structures may be especially crucial. Children's causal explanations both demonstrate their understandings of the world and, like their questions (Chouinard, 2007), may constitute a mechanism for advancing causal learning and the acquisition of knowledge (Amsterlaw & Wellman, 2006; Bartsch & Wellman, 1989; Callanan & Oakes, 1992; Gopnik & Meltzoff, 1997; Siegler, 1995; Wellman, 2011).

Causal explanation is a goal-directed human activity. It depends on what is relevant or important to the person constructing an explanation. A desire to understand may underlie the motivation to construct an explanation (Gopnik, 1996). According to Gopnik (1996, 2000), the phenomenology or experience of explanation is an essential component of the task of explanation. One possibility is that a drive to explain evolved because generally speaking, it aids in learning and contributes to an increasingly accurate understanding of the causal structure of the world around us. There is mounting evidence that a strong interest in constructing explanations may indeed be especially beneficial for learning in childhood (Legare & Lombrozo, 2014; Walker, Lombrozo, Legare, & Gopnik, 2013).

Emerging developmental research has demonstrated a greater focus on the development of explanation. To the extent that explicit “why” questions and “because” answers can be used as prototypical indices of explanatory reasoning, developmental research indicates that both explanations and requests for explanation are widespread even in very young children (Frazier, Gelman, & Wellman, 2009; Keil, 2006; Keil & Wilson, 2000). Research examining preschoolers’ everyday conversations with their caregivers has demonstrated that causal explanations increase in frequency with age but are common even at 2-3 years of age (Callanan & Oakes, 1992; Crowley et al., 2001; Wellman, Hickling, & Schult, 1997). Furthermore, causal explanations most typically serve an epistemic function; that is, they provide an interpretation for a current or past event, and do not serve an exclusively social-regulatory function (Hickling & Wellman, 2001). Given the proliferation of explanatory activity young children engage in: What triggers or motivates children to generate causal explanations?

Contrastive outcomes, counterfactuals, and causation

To investigate the kinds of events children are most compelled to explain, we turn now to a discussion of when children’s explanations involve invoking a contrastive or counterfactual case, as opposed to focusing exclusively on the event-to-be-explained. Counterfactual thinking entails mentally comparing the observed case with alternative cases, and this process may direct attention to and provoke interest in inconsistent outcomes. When observing an event, children build a representation of the event that they use to interpret, explain, and predict its outcomes. Causal judgments often involve a contrast between a perceived sequence and a counterfactual case (Hilton & Slugoski, 1986), and developmental research indicates that preschool children use counterfactual

thinking in causal reasoning (Harris, German, & Mills, 1996). That is, in order to identify a new outcome children often notice contrastive outcomes and identify the conditions that are causally responsible for differences between the outcomes. Contrary to the Humean account of causal learning, Mackie (1974) argues that our beliefs about causality are not based exclusively on repeated observations but also on an interpretation of what is observed and what might have been observed instead.

Although research using contrastive outcomes with children is limited (but see Harris, et al., 1996), research on infant cognition relies heavily on the use of contrastive outcome tasks as a way to prime and assess infants' expectations. Infant cognition research provides support for the hypothesis that inconsistent or problematic outcomes are compelling from a very early age (Wang, Baillargeon, & Brueckner, 2004). Violation-of-expectation (VOE) tasks have been widely used to assess infants' understanding of physical (Baillargeon, 2002) and psychological (Onishi, Baillargeon, & Leslie, 2007) phenomena, based on the assumption that infants: (a) have expectations, (b) are surprised when these expectations are violated, and (c) index surprise by showing greater attention as determined by increased looking time. In a typical VOE experiment, infants watch two test events, one consistent with the expectation examined in the experiment (expected event) and one inconsistent (unexpected event). In order to introduce potentially unfamiliar test stimuli or establish specific expectations, prior to the test trials, infants usually view habituation or familiarization trials. With appropriate controls, evidence that infants look reliably longer at the unexpected than at the expected event is taken to indicate that they possess the expectation under investigation, detect the violation in the expected event, and are surprised by this violation (Wang et al., 2004).

However, it is difficult to tell whether these responses (typically measured as heightened attention or arousal) from infants are truly demonstrating surprise, or even expectation-violation. Moreover with infants, one cannot tell for sure if they are actively exploring or genuinely seeking more information. For example, there is no good evidence that longer looking time corresponds to other measures of emotional state (Haith & Benson, 1997; Haith, 1998; Wang et al., 2004). Although claims about explanatory phenomenology and expectation violation have been amply made in the infancy literature, there is still a big gap between the behaviors that can be measured (such as looking time) and the phenomenon of theoretical interest (for present purposes, whether an event is in need of explanation). Therefore, examining explanatory reasoning with older children may provide us with more concrete insights into the development of causal reasoning.

Children's causal explanations do more than demonstrate their understandings of the world through verbal articulation: they may also constitute a mechanism for advancing causal learning and the acquisition of knowledge (Legare, 2012; 2014; Lombrozo, 2006). Moreover, because children are actively engaged in developing causal knowledge structures, constructing explanations may engage their emerging curiosity and understanding. Additionally, prototypical indices of explanatory reasoning such as "why" questions and "because" answers indicate that both explanations and requests for explanation are widespread even in 2-year-olds (Frazier et al., 2009; Keil, 2006; Keil & Wilson, 2000).

Explanatory triggers

Because young children have so much to learn, they have much to explain. How do children navigate the task of causal learning and what motivates children to construct causal explanations? We propose that explanatory biases play an important role in guiding children's causal explanations. Children make use of causal-explanatory understanding to explain *consistent events* (when events unfold as anticipated based on prior knowledge) but also to recognize and attempt to explain *inconsistent events* (when something unusual or discordant with prior knowledge happens). Accordingly, children's explanations may serve at least two distinct functions. One possibility is that explanation serves as a mechanism for confirming children's prior knowledge. Children are early in the process of developing explanatory knowledge and are faced with the considerable task of navigating an infinite number of outcomes and events that could potentially warrant explanation. Therefore, consolidating and confirming their explanations for events consistent with prior knowledge and experience may be especially attractive and beneficial.

Another possibility is that because children anticipate regularity or consistency with prior beliefs, they may therefore find *outcomes inconsistent with prior knowledge* especially worthy of explanation. For example, children may expect an object to continue to function or a person to continue to behave in a manner consistent with prior experience. Alternative functioning or anomalous behavior would therefore be inconsistent outcomes.

We propose that (a) events inconsistent with prior knowledge are especially powerful triggers for explanatory reasoning and (b) events consistent with prior knowledge are less likely to motivate children to construct explanations. Although the

idea that inconsistent, problematic, or surprising outcomes play an important role in causal reasoning appears across multiple literatures--philosophy of science (Hempel, 1965), social psychology (Hilton, 1995), educational research (Chi, Bassok, Lewis, Reimann, Glaser, 1989), and infancy research (Baillargeon, 2002)--there is remarkably little empirical research on what motivates causal explanations in children and how this can inform the developmental trajectory of causal explanation.

How might these alternative possibilities be tested? Imagine that a child sees two equivalent events, one in accord with prior knowledge and the other not. If explanation is largely confirmatory, children should simply explain what they already have an explanation for. If explanation is instead responsive to discordant or anomalous information, children should explain the event that falls outside their prior knowledge or expectations. This is the scenario Legare and colleagues used as an experimental paradigm to examine these competing hypotheses about the function of children's explanations (Legare & Gelman, 2014; Legare, et al., 2010; Legare, 2012). Moreover, they examined the nature of children's explanations, specifically whether children provided explanations primarily in terms of surface features and past histories, or whether they offered explanations focused on less-obvious properties.

To address these issues experimentally, Legare and colleagues designed a task with a set of novel "light boxes" – electronic devices which glowed bright when activated (Legare et al., 2010). The activation and deactivation of the boxes were experimenter-controlled, but appeared to be caused by objects placed on the surface of each box (materials were modeled after those used in Gopnik & Sobel, 2000; Gopnik et al., 2001). These materials were used to teach children about different categories of objects, where

within each category items were both perceptually identical and shared common causal properties. Objects were labeled according to their causal properties: “starters” were objects which activated the light box when placed on top of it, “stoppers” were objects which deactivated the light box when placed on top of it, and “do-nothings” were objects which could neither activate nor deactivate the light box. After training, children were presented with scenarios in which a new object that looked like one type (for example, it looked like a “starter”) actually behaved like another type (behaved like a “do-nothing”; inconsistent event). This was paired with an object that looked and behaved like those previously seen (looked like a “do-nothing” and behaved like a “do-nothing”; consistent event). Upon viewing such paired outcomes, children were asked a non-specific explanatory question ambiguously referring to either (visible) outcomes: “Why did that happen?”

An important feature of the design of this study was experimentally differentiating the kinds of events that children find noteworthy and therefore feel compelled to explain. The events that led to greater interest and attention, and most importantly, increased explanation, were examined. If the role of explanations for children is confirmatory, children should have been interested in and provided explanations for the consistent event in this pair. If inconsistency plays a special role in motivating children to construct explanations, they would then be specifically interested in and provide hypotheses and explanations for the inconsistent event. The results indicated that children were most likely to first explain an inconsistent rather than a consistent event (Legare et al. 2010).

A second objective of the study was to examine the types of explanations children

generated. Children could have referred to a variety of features in their explanations – surface appearances, underlying causal properties and past histories, or category membership. Even children as young as 3 years of age can categorize objects in terms of novel, non-obvious properties (Jaswal & Markman, 2007; Graham, Kilbreath, & Welder, 2004; Gelman & Coley, 1990; Gelman & Markman, 1986, 1987), apply names to objects with the same functional properties (Kemler-Nelson, 1995), and categorize and name objects based on novel causal properties (Gopnik & Sobel, 2000), overriding perceptual appearances. If information about an object’s underlying causal properties or function is central to how children categorize and reason about objects, information about function and underlying causal properties should be found in children’s causal explanations. The results of Legare et al. (2010) demonstrate that the content of children’s explanations for inconsistent outcomes was more likely to refer to internal causal properties, include information about causal function, and override perceptual appearances than consistent outcomes. The findings suggest that inconsistent events motivate children to construct more sophisticated explanations and provide evidence consistent with the proposal that children’s causal explanations function in the service of discovery.

Summary

A growing body of research supports the proposal that children’s explanations provide unique insight into the development of causal reasoning. Research examining explanatory biases has demonstrated that inconsistency with prior knowledge motivates children to construct explanations (Legare et al., 2010), guides discovery-oriented behavior, and constrains the early developing capacity to reason scientifically (Legare, 2012; 2014).

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