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Young children revise explanations in response to new evidence

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ABSTRACT

Revising explanations when faced with new evidence is essential to the learning process. Two studies with 3- to 6-year-olds examined the capacity to generate and revise explanations in response to different kinds of evidence within and across domains. In Study 1 ($N = 60$) children were presented with new evidence about an alternative individual preference that was inconsistent with children's prior beliefs. In Study 2 ($N = 60$) the new evidence was biological rather than psychological. The data demonstrate that children are more likely to first explain inconsistent than consistent psychological outcomes and that children revise explanations for inconsistent outcomes in response to new evidence, both within and across domains.

1. Introduction

A substantial and influential body of research has documented that children's explanations provide insight into the development of causal knowledge and conceptual understanding (Callanan & Oakes, 1992; Frazier, Gelman, & Wellman, 2009; Hickling & Wellman, 2001; Keil & Wilson, 2000; Keil, 2006; Schult & Wellman, 1997; Wellman, Hickling, & Schult, 1997). Yet explanations reveal more than just what children know; new research supports the proposal that explanation plays an important role in scaffolding the learning process (Bonawitz, van Schijndel, Friel, & Schulz, 2012; Brewer, Chinn, & Samarapungavan, 1998; Legare, 2012; Lombrozo, 2006) and may be developmentally privileged (Legare, Wellman, & Gelman, 2009; Wellman & Liu, 2007). If explanation is a powerful and widespread mechanism for acquiring knowledge and constructing new understanding, children should not only be motivated to seek out and construct explanations for the complex world around them; they should also flexibly revise explanations in response to new information.

Explaining why a phenomenon occurs is one of the fundamental objectives of the scientific process and an important goal of science education (Gelman, Brenneman, Macdonald, & Román, 2010). Despite the widely documented educational benefits of generating explanations (Amsterlaw & Wellman, 2006; Chi, 2000; Chi, DeLeeuw, Chiu, & LaVancher, 1994; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Crowley & Siegler, 1999; Lombrozo, 2006; deLeeuw & Chi, 2003; McEldoon, Durkin, & Rittle-Johnson, 2012; McNamara, 2004; McNamara, O'Reilly, Rowe, Boonthum, & Levinstein, 2007; Rittle-Johnson, Saylor, & Swygert, 2008; Williams & Lombrozo, 2010, 2013) and the acknowledged importance of generating explanations for cognitive development (Gopnik, 2000; Wellman, 2011), the cognitive process by which explanations contribute to the

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discovery of new information and the construction of more sophisticated knowledge has only been studied recently in early childhood (Legare & Lombrozo, 2014; Legare, Zhu, & Wellman, 2013; Walker, Lombrozo, Legare, & Gopnik, 2014). In the current studies we investigated the kinds of events that motivate explanation-revision in early childhood.

We hypothesize that explanation is most efficacious when harnessed to understand inconsistency and that children flexibly revise their explanations in response to new information. If explanation plays a role in acquiring new information and constructing new understanding, then learners should explain the observations that have the greatest potential to teach them something new; namely, those that are *inconsistent* with respect to their current knowledge and thus motivate further information seeking. We operationalize consistent outcomes as events that conform to expectations based on prior knowledge, and inconsistent outcomes as events that violate expectations based on prior knowledge. Biases to explain inconsistent and ambiguous information could aid in learning by focusing children on events that challenge current causal knowledge and provoke additional, amended causal reasoning by increasing awareness of uncertainty and the potential for multiple interpretations of the same information (Bonawitz, Fischer, & Schulz, 2012; Legare, 2012; Stahl & Feigenson, 2015).

This proposal finds support in recent work examining the biases that motivate children to provide explanations. In a series of studies with preschool children, Legare et al. have examined the kinds of events that prompt explanation and how explanatory biases provide insight into the function of explaining (Legare, 2012; Legare, Gelman & Wellman, 2010; Legare & Gelman, 2014). The results of these studies indicate that outcomes inconsistent with prior knowledge are especially powerful triggers for children's explanations, and that the explanations children provide for inconsistent outcomes refer to unobserved causal mechanisms and internal causal properties, overriding perceptual biases. This suggests that explanation provides children with the opportunity to articulate new hypotheses for events that, at first, disconfirm their current state of knowledge (Legare, 2014; Walker, Williams, Lombrozo, & Gopnik, 2012). Although these studies did not directly measure learning, the data they present are consistent with the proposal that children's explanations play an active role in the learning process and provide an empirical basis for investigating the mechanisms by which children's explanations function in the service of discovery.

Despite evidence that inconsistent outcomes trigger causal explanations more often than consistent outcomes (Legare et al., 2010), it is unclear why inconsistency motivates children to generate explanations. One possibility is that children may interpret such information as ambiguous or as supporting multiple interpretations. New information may appear superficially to be inconsistent but in fact opens up the hypothesis space to alternative interpretations. When faced with information that appears inconsistent with prior knowledge (e.g., an actor chooses not to select their favorite food), there are multiple potential explanations (e.g., actor's preference could have changed, something about the particular favorite item that was undesirable). Thus, inconsistency is inherently ambiguous and it may be this ambiguity or uncertainty that motivates the bias to explain inconsistent outcomes (Foster & Keane, 2015; Lipton, 2004).

Notably, merely attending to inconsistency does not always lead to explanation revision (Bindra, Clarke, & Shultz, 1980; Dunbar & Klahr, 1988; Fay & Klahr, 1996; Kuhn, 1989; Vosniadou & Brewer, 1992, 1994). For example, one can ignore inconsistent evidence, reject it, declare it beyond the scope of the theory in question, or postpone coming to terms with the new evidence (Chinn & Brewer, 1993). Encouraging children to explain inconsistency may serve as a critical mechanism for integrating and reconciling discordant or ambiguous information with existing theories and may reduce engagement in theory-preserving strategies like rejection and postponement.

But how might the process of explaining inconsistent information generate amended beliefs? One possibility is that explaining encourages learners to formulate and entertain hypotheses they would not have spontaneously considered otherwise. Generating hypotheses in the service of explanation may influence the kinds of hypotheses formulated, as well as their impact on cognition (Bonawitz, Fischer et al., 2012; Bonawitz, van Schijndel et al., 2012; Legare & Lombrozo, 2014; Walker et al., 2014, 2012). In particular, both children and adults have strong intuitions about what makes something a good explanation (Bonawitz & Lombrozo, 2012; Frazier et al., 2009; Lombrozo, 2007), and explanation may promote the production of hypotheses that are judged as informative.

The capacity to actively revise existing hypotheses when faced with new information is an essential component of knowledge acquisition. Although explanation revision is widely acknowledged as core features of cognitive development (Gopnik & Schulz, 2007), little is known about the role explanation may play in this process. Given the bias to explain inconsistent outcomes (Legare et al., 2010), children may be particularly receptive to new information surrounding an inconsistent event, respond flexibly to new information, and incorporate this information into their developing explanatory frameworks. It is also possible, however, that incorporating new information into their previous explanations may pose a considerable cognitive challenge for young children. For example, when faced with new information potentially relevant to a previous explanation for an inconsistent outcome, children may use their first explanation as an 'anchor,' and this will serve as a bias against incorporating new evidence into their explanations (Tversky & Kahneman, 1974). It may also be the case that the tendency towards a confirmation bias may inhibit the capacity to incorporate new evidence into existing explanations. In the current research we examine the extent to which constructing a causal explanation for inconsistent outcomes informs and constrains children's capacity to formulate and revise explanatory hypotheses.

We are especially interested in the capacity to incorporate new information from within and across different intuitive domains into existing explanations. Prior research indicates that children use intuitive, domain-specific, foundational theories to organize information, interpret observations, and reason about novel situations (Wellman & Gelman, 1992). Human actions can have psychological, physical or biological causes, and thus provide an optimal context for studying the children's explanations across domains. Research into children's explanations of human actions showed that young children are capa-