Children' s Selective Learning in the Domain of Causal Knowledge

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Abstract

Children' s selective learning is currently a prominent topic in the field of cognitive development. Selective learning within the domain of causal knowledge (i.e., selective causal learning) holds significant importance for addressing the classic question of how children acquire knowledge. Children' s selective causal learning is manifested in the discrimination, evaluation, and adoption of others' explanations. They actively seek explanations from reliable informants and demonstrate selective follow-up responses upon receiving answers. With respect to others' responses, younger children can not only discriminate explanatory statements based on verbal cues but also select superior statements for adoption according to the structural features of explanations; older children can even flexibly learn more appropriate causal knowledge from different modes of explanation. Future research should thoroughly investigate the role of other features of explanations in children' s selective causal learning and further explore the cognitive mechanisms underlying this process.

Full Text

Preamble

Children' s Selective Learning in the Domain of Causal Knowledge

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Abstract
Children' s selective learning has become a prominent topic in cognitive development research. Selective learning in the domain of causal knowledge—referred to here as "selective causal learning" —offers crucial insights into the

classic question of how children acquire knowledge. Children demonstrate selective causal learning through their ability to discriminate, evaluate, and adopt others' explanations. They actively seek explanations from reliable informants and exhibit selective follow-up responses after receiving answers. Even young children can identify explanatory statements based on verbal cues and select superior statements according to structural features. Older children can flexibly learn more appropriate causal knowledge from different explanatory modes. Future research should further examine the role of other explanatory features in children' s selective causal learning and investigate the underlying cognitive mechanisms.

Keywords: selective learning; causal knowledge; explanation-seeking; explanatory qualities/virtues; modes of construal
Classification Code: B844

1 Introduction

Research on children' s cognitive development aims to uncover the principles underlying children' s concept formation, language acquisition, and knowledge acquisition. Some researchers view children as "little scientists" who form concepts and acquire knowledge through their own exploratory activities (Gopnik & Wellman, 2012; Piaget, 1929). Others consider children "little anthropologists" who continuously absorb experiential knowledge transmitted by others through social interaction (Harris, 2012; Legare & Harris, 2016; Vygotsky, 1980). This process of learning new knowledge through interaction with other individuals or social products (such as books and tools) is termed "social learning" (Hoppitt & Laland, 2013). Social learning is crucial for children' s cognitive development and has attracted sustained attention not only from developmental psychology but also from cognitive science, anthropology, evolutionary biology, and other disciplines (Heyes, 2017; Heyes & Pearce, 2015; Kendal et al., 2018; Koenig & Sabbagh, 2013; Poulin-Dubois & Brosseau-Liard, 2016; van Leeuwen et al., 2018).

Understanding the world is children's primary developmental task, with learning about causal relationships being paramount (Bridgers, Buchsbaum, Seiver, Griffiths, & Gopnik, 2016). By understanding causal relationships between events, children can explain, predict, and control their environment. Children' s causal learning depends not only on physical cues (Gopnik, 2012; Lucas, Bridgers, Griffiths, & Gopnik, 2014; McCormack, Frosch, Patrick, & Lagnado, 2015) but also on social cues (Bridgers et al., 2016; Ronfard, Chen, & Harris, 2018). Research shows that children acquire much of their knowledge from others' testimony (Harris, Koenig, Corriveau, & Jaswal, 2018; see also Gelman, 2009; Harris & Koenig, 2006; Mills & Landrum, 2014). Testimony refers to information—containing an individual' s thoughts or beliefs—transmitted through language (Sosa, 1991), typically in the form of assertive statements from informants to recipients (Coady, 1992; Zhang & Zhu, 2014). While children can acquire causal knowledge more quickly and effectively through others' testimony, not all transmitted infor-

mation is accurate or worth learning. How children discriminate and evaluate information and information sources, and selectively adopt others' knowledge, constitutes the core research content of selective learning (Sobel & Kushnir, 2013; see also Brosseau-Liard, 2017; Koenig & Sabbagh, 2013; Poulin-Dubois & Brosseau-Liard, 2016).

Explanation is a vital component of causal learning, helping people understand the world, form concepts, and guide cognitive activities (Cimpian & Keil, 2017). In social learning, explanations represent others' testimony about causal knowledge. Consequently, how children discriminate, evaluate, and adopt others' explanatory testimony lies at the heart of selective learning in the domain of causal knowledge. This article reviews relevant research on children' s selective learning in the domain of causal knowledge, examining the process by which children actively seek explanations from others, select among the explanations provided, and learn causal knowledge from them (hereafter referred to as "selective causal learning"). We explore children' s abilities to identify explanatory information and select high-quality or appropriate explanations.

2 Children' s Active Seeking of Explanatory Testimony

When encountering unknown or uncertain situations, even preverbal infants actively seek information from others (Harris, Bartz, & Rowe, 2017; Schulz, 2012; see also Goupil, Romand-Monnier, & Kouider, 2016; Stahl & Feigenson, 2015). Through communication with knowledgeable individuals, children learn substantial amounts of knowledge, particularly causal knowledge (Baldwin & Moses, 1996; Rogoff, 1998; Ronfard, Bartz, Cheng, Chen, & Harris, 2018). Inquiring behavior represents an important way for children to seek information from others.

Inquiring behavior refers to communicative acts through which individuals express questions to seek information from others (Baldwin & Moses, 1996) and constitutes an active exploratory activity mediated by language. As children master language, inquiring becomes a common and important form of social learning. It is through extensive inquiring that children rapidly and accurately acquire the cultural wealth accumulated over generations (Legare, 2017; Legare & Harris, 2016; Tomasello, 2016). Research shows that preschool children' s questions cover a wide range of topics, including behavioral purposes, cultural customs, natural phenomena, biological knowledge, and mechanical principles (Callanan & Oakes, 1992; Chouinard, 2007; Greif, Kemler Nelson, Keil, & Gutierrez, 2006; Kelemen, Callanan, Casler, & Perez-Granados, 2005). These include both fact-based questions (seeking "what" information) and explanation-based questions (seeking "why" and "how" information). Additionally, research indicates that as children age, they gradually shift from asking primarily fact-based questions to seeking explanations (Frazier, Gelman, & Wellman, 2009; Hickling & Wellman, 2001; Kurkul & Corriveau, 2018). Consequently, explanation-seeking (asking explanation-based questions) has become the main manifestation of children' s inquiring behavior and an important means of social

learning in the domain of causal knowledge.

Children' s explanation-seeking comprises three components: Question, Response, and Follow-up (Kurkul & Corriveau, 2018), with the questioning process further subdivided into Initiation, Formulation, and Expression (Ronfard, Zambrana, Hermansen, & Kelemen, 2018). Research shows that both the questioning and follow-up stages of preschoolers' explanation-seeking exhibit selectivity: young children choose to seek explanations from reliable individuals (Kushnir, Vredenburgh, & Schneider, 2013; Lane & Harris, 2015; Mills, Legare, Grant, & Landrum, 2011). If others' explanations are satisfactory, children express affirmation or ask deeper follow-up questions; otherwise, they express dissatisfaction, restate their questions, or sometimes attempt to provide their own explanations (Callanan & Oakes, 1992; Chouinard, 2007; Frazier et al., 2009, 2016; Kurkul & Corriveau, 2018).

The questioning and follow-up stages reflect different aspects of selectivity: the questioning process reflects how explanation-seeking emerges, while the follow-up stage reflects how inquiring behavior concludes or further develops. Children seek explanations to acquire explanatory information, and their reactions in the follow-up stage after receiving information represent manifestations of selective causal learning. Therefore, this article focuses on elucidating the process by which children selectively learn from others' explanations (i.e., how children discriminate, evaluate, and adopt explanatory information provided by others) and the role of explanation features (verbal cues, structural characteristics, modes, etc.) in children' s selective causal learning.

3 The Role of Explanation Features in Children' s Selective Causal Learning

Explanations and causal knowledge are inseparable: explanations typically need to include the reasons behind phenomena and properties, while causal knowledge is often used to account for why things exist or how they change (Lombrozo & Vasilyeva, 2017). Explanations help children construct concepts and master regularities, making learning good causal explanations crucial for cognitive development. Selectively learning from others' explanations first requires children to discriminate whether others' testimony contains explanatory information. Second, children must distinguish better explanations from multiple explanatory statements and adopt them. Finally, children need abstract understanding to select more appropriate explanations for learning based on the problem at hand.

3.1 Verbal Cues of Explanations

Before selecting good explanations for learning, children must be able to identify valid explanations from the information others provide. Verbal cues of explanations refer to pragmatic or semantic features that indicate a statement has explanatory function. Children can use verbal cues to distinguish explanatory from non-explanatory statements from an early age. For example, Bernard,

Mercier, and Clement (2012) presented 3- to 5-year-olds with two types of statements describing an object' s location. One type included causal connectives, such as "The ball is in the blue box because Camille always puts it there," while the other replaced the causal connective with a discourse marker: "The ball is in the green box, well, Camille always puts it there." Results showed that 4- and 5-year-olds searched for the object in the location indicated by the statement containing the causal connective, demonstrating that preschoolers can determine whether a statement contains explanatory information through simple verbal cues like causal connectives.

Preschoolers can identify explanatory statements based on the presence or absence of causal connectives, but they do not rely exclusively on them. Even when others' statements lack causal connectives, preschoolers can still discriminate whether the statements explain the question. Frazier et al. (2009, 2016) found that 3- to 5-year-olds expressed dissatisfaction with responses such as repetitions ("You' re right, there' s a turtle in the nest"), descriptions of norms ("People don' t usually wear red noses like that"), or personal preferences ("I like to pour milk on my cereal"). These children were more likely to restate their questions or attempt their own explanations. In contrast, they showed greater satisfaction with explanatory statements that similarly lacked "because" connectives, displaying more agreement and deeper follow-up questions. Frazier et al. (2016) also found that preschoolers construct memories when recalling others' non-explanatory statements. They not only spontaneously add causal connectives ("because···") when recalling others' responses but even transform non-explanatory answers into "explanatory statements" with causal connectives. These results indicate that causal connectives serve merely as perceptual cues for children to distinguish whether statements are explanatory; the semantic content of statements is the key to their judgment.

Furthermore, some statements contain causal connectives but provide no substantive causal information. For instance, circular explanations restate the content of the question without adding meaningful new information (Baum, Danovitch, & Keil, 2008; Corriveau & Kurkul, 2014). Distinguishing circular from non-circular explanations requires more mature discriminative abilities. Researchers presented 6- and 10-year-olds with circular and non-circular explanations of equal length, where circular explanations merely restated question content while non-circular explanations provided causal information. Results showed that 6-year-olds could already distinguish between the two types and demonstrated a bias toward non-circular explanations (Baum et al., 2008). Other studies have found that even younger children can differentiate circular and non-circular explanations and prefer non-circular ones (Castelain, Bernard, & Mercier, 2018; Castelain, Bernard, Van der Henst, & Mercier, 2016; Mercier, Bernard, & Clement, 2014). For example, researchers presented young children (ages 2-5) with pictures of hybrid objects (e.g., an object with 75% bird features and 25% fish features). An informant then provided identical labels accompanied by different explanatory justifications (circular: "This is a fish because it looks like a fish to me" ; non-circular: "This is a fish because I' ve seen it

swimming in water"). Results showed that even 2-year-olds significantly preferred to accept the non-circular explainer' s subsequent labeling of new stimuli (Castelain et al., 2018). These studies demonstrate that discriminating valid explanatory statements from circular explanations is an early-developing capacity in selective causal learning and forms the foundation for children to accurately and effectively adopt others' explanations.

Meanwhile, young children' s ability to discriminate explanatory statements also serves their social inference processes (such as inferring others' credibility) (Corriveau & Kurkul, 2014; see also Doebel, Rowell, & Koenig, 2016). In one study, experimenters presented preschoolers with two informants' explanations for natural phenomena (e.g., "Why does it rain?"), where one always provided circular explanations (e.g., "It rains because water falls from the sky and gets us wet") and the other always provided non-circular explanations (e.g., "It rains because clouds fill with water and accumulate too much"). Results showed that 3- to 5-year-olds tended to trust the non-circular explainer when encountering unfamiliar objects and novel phenomena (Corriveau & Kurkul, 2014). This indicates that preschoolers can not only discriminate valid explanations based on semantic differences in testimony but also infer informants' reliability based on these information characteristics. Such social inferences can also serve children' s explanation-seeking behavior by helping them identify reliable explanation providers in their environment, ensuring accurate and effective adoption of others' testimony.

In summary, children can infer whether others' responses are worth learning based on verbal cues of explanations. Preschoolers clearly recognize words associated with explanations, understand semantic differences between statements with and without explanations, and can even distinguish circular from non-circular explanations. These findings demonstrate that children can identify whether others provide causal explanations at the lexical level and select meaningful explanatory statements at the sentence level (non-circular explanations containing new information) while inferring informants' credibility. Judging whether statements contain meaningful new information is necessary when learning causal knowledge from others' explanations. However, this ability alone is insufficient for children to identify high-quality explanations, making the question of whether children can evaluate and choose among equally meaningful but differentially meritorious explanations worthy of attention.

3.2 Structural Features of Explanations

Children can not only use verbal cues to distinguish explanatory from non-explanatory statements but can also evaluate the relative quality of explanations. Like adults, children attend to "explanatory qualities" or "virtues" when evaluating explanations (Glymour, 2015; Lombrozo, 2016). Existing research has examined how structural features related to explanatory quality influence children' s selective causal learning, focusing primarily on explanatory simplicity and breadth.

3.2.1 Explanatory Simplicity Explanatory simplicity refers to the degree of parsimony in the number of causes included in an explanation (Bonawitz & Lombrozo, 2012; Lombrozo, 2007, 2012). When comparing multiple explanatory statements, even if they all articulate causal relationships, adults typically consider explanations that posit simple causal relationships to be superior. Compared to complex explanations (containing two independent antecedents), adults show an a priori bias toward simple explanations (containing a single common antecedent) (Lombrozo, 2007).

Research with preschoolers has yielded consistent results. Bonawitz and Lombrozo (2012) introduced a novel toy to 4- to 6-year-olds where placing different colored wooden pieces in the toy' s activation slot produced different outcomes: blue pieces caused the toy to spin and light up, green pieces caused only spinning, and red pieces caused only lighting. When the experimenter accidentally knocked over a bag of pieces, causing both the light and windmill to activate, children were asked to explain the possible cause. The study found that 4- and 5-year-olds tended to identify the blue piece as the activator, indicating that preschoolers favor simple explanations containing a single common antecedent.

Walker, Bonawitz, and Lombrozo (2017) replicated these findings using problems from other domains. In a more contextualized experiment, 4- to 6-year-olds were shown two unhealthy plants (growing in different garden locations) and asked why the plants were sick. Experimenters provided two possible explanations: a common-cause explanation (soil type caused both plants to become sick) or independent-cause explanations (a bad sprinkler and lack of sunlight caused the two plants to become sick, respectively). Results revealed developmental differences in children' s bias toward simple explanations: 4-year-olds showed no significant preference for either explanation, while 5-year-olds partially demonstrated a preference for simple explanations. These studies indicate that children in late preschool show a clear simplicity bias, beginning to attend to the simplicity of explanatory (causal) structures like adults.

Both children and adults' explanation selection is influenced by the simplicity of causal structures in statements, though the reasons remain debated. On one hand, people' s preference for simple explanations represents a rational choice. Researchers distinguish between node simplicity (reflected in the total number of antecedents included in an explanation) and root simplicity (reflected in the number of unexplained antecedents), finding that adults specifically show a preference for root simplicity (Pacer & Lombrozo, 2017). Root-simple explanations streamline complex causal relationships, facilitating memory, analysis, and transmission. Additionally, people perceive the probability of predicting effective outcomes from or controlling for a single antecedent as relatively greater. Therefore, choosing simple explanations and preferring causally simple structures has certain rationality.

On the other hand, preference for simple explanations may result from heuristic judgment. Research shows that when probability information is difficult to compute, the a priori probability of complex explanations must be nearly 10 times

stronger than that of simple explanations for adults to abandon their "blind" preference for simplicity (Lombrozo, 2007). When probability information can be computed, adults no longer show a simplicity bias and instead support more probable explanations even if they require more antecedents, whereas 4- to 6-year-olds still tend to accept simple explanations (Bonawitz & Lombrozo, 2012). This suggests that the simplicity bias may be a heuristic that provides a basis for choice when rational judgment is impossible.

In summary, preschool children, like adults, show a preference for explanatory simplicity. However, the cognitive mechanisms underlying this preference remain controversial. Are young children born with a heuristic preference for simple explanations, or do they gradually acquire the rational inference that "simple explanations are better" through experience evaluating explanatory testimony? Future research should directly test this question and further explore the cognitive mechanisms underlying children' s preference for simple explanations. This would help researchers understand rationality in individual causal learning and its development.

3.2.2 Explanatory Breadth Explanatory breadth refers to the scope of observable results that an explanation can cover (Khemlani, Sussman, & Oppenheimer, 2011). Both children and adults consider not only simple but also broad explanations to be good explanations (Johnston, Johnson, Koven, & Keil, 2017).

Young children already recognize the role of explanatory breadth in learning concepts and understanding phenomena. Research shows that when evaluating explanatory statements about biological phenomena, 5- to 7-year-olds consider general statements (e.g., "All animals···") better than less general ones (e.g., "All bears···") (Johnston, Sheskin, Johnson, & Keil, 2018). When learning causal relationships, children and adults also prefer statements with broader scope—that is, explanations covering more observed phenomena (Johnston et al., 2017). However, children' s preference for broad explanations is not blind. For example, when learning concepts or phenomena in physics, 5- to 7-year-olds do not show a preference for more general explanatory statements (Johnston et al., 2018). Children need to possess understanding of abstract physical laws (such as gravity) to comprehend the universality of certain physical explanations. Therefore, before acquiring necessary abstract knowledge, children evaluate explanatory breadth cautiously.

Other research has examined children' s bias toward explanations' latent scope, which refers to the number of unconfirmed results included in an explanation (Johnson, Rajeev-Kumar, & Keil, 2014, 2016; Khemlani et al., 2011). Researchers presented adults and children (ages 4-8) with explanations for events that either included only observable phenomena or also contained unconfirmed phenomena. Results showed that both adults and children preferred explanations with narrow latent scope (containing fewer unconfirmed phenomena) (Johnston et al., 2017).

In summary, broad explanations provide children with opportunities to make inferences across different contexts, enabling more efficient learning of domain-relevant knowledge. Simultaneously, children do not blindly prefer broad explanations but can reasonably select explanations based on breadth cues. Therefore, preference for explanatory breadth may result from rational choice in both children and adults.

Existing research has primarily examined how explanatory quality influences people' s inferences about superior explanations. Studies consistently find that, like adults, children not only collect probability information to infer causal regularities but also select and learn from high-quality explanations based on explanatory quality (Lombrozo, 2016; see also Lipton, 2004). When directly comparing explanatory quality and probability, both adults and children assign greater weight to explanatory quality, sometimes choosing explanations with lower posterior probability under the influence of explanatory quality (Bonawitz & Lombrozo, 2012; Johnston et al., 2017). Preference for certain explanations based on quality may stem from heuristic knowledge formed through experience or from rational selection of highly effective explanations (Pacer & Lombrozo, 2017). Both heuristic and rational judgment processes play important roles in children' s selective causal learning, complementing each other. Heuristic processes help children respond automatically and rapidly, while rational judgment helps them make more flexible responses through inference in complex situations (e.g., Hermes, Behne, & Rakoczy, 2018). When and how these cognitive processes operate in children' s selective causal learning remain questions requiring deeper investigation.

3.3 Modes of Construal

When facing multiple explanations, children and adults select superior testimony based on explanations' structural features, aligning with researchers' essentialist view of explanation. This perspective holds that for any question requiring explanation, only one explanation is most reasonable—there exists an essence of "bona fide" explanation (Salmon, 1989). That is, among many explanations, those approaching this true essence are better. However, this view is overly absolute and context-independent, failing to account for how individuals develop different understandings of the same question. Any explanatory question can elicit multiple possible answers that differ in content and mode of understanding (van Fraassen, 1980; see also Vasilyeva, Wilkenfeld, & Lombrozo, 2015). Therefore, some researchers hold a pragmatist view of explanation, suggesting that many explanations are reasonable for any given question, with no single absolutely reasonable one. The process of generating explanations involves selecting from many reasonable explanatory statements those that fit the question' s context (Chin-Parker & Bradner, 2010; van Fraassen, 1980).

3.3.1 Classification of Explanation Modes Explanations are often used to answer "why" and "how" questions, but explanatory questions do not have only

one solution. For example, "Why do deer have spots?" could be explained as "It' s caused by the deer' s genes and prenatal environment" or "It' s camouflage to help deer hide from predators" (Lombrozo & Wilkenfeld, 2018). Both statements answer the same question but involve different causes (Lombrozo, 2010, 2012).

Since ancient Greek times, philosopher Aristotle proposed the "Four Causes" to clarify different aspects of explanation (Falcon, 2015; Lombrozo, 2006). Efficient cause identifies proximate mechanisms, answering "how come" questions by explaining the origin and process of phenomena; final cause identifies functions, purposes, and end states, answering "what for" questions by explaining results and meanings. Additionally, formal cause uses categorical relationships between things to explain property origins, while material cause uses compositional properties to explain property characteristics. This classification of causes continues to influence researchers' understanding of different explanations. Psychologists studying children' s explanatory and predictive patterns across knowledge domains have found that young children possess multiple modes of construal (Keil, 2006), including teleological and physical modes, corresponding to Aristotle' s final and efficient causes.

Based on this understanding, researchers have classified explanations accordingly. Some have categorized parents' everyday explanations to their children into teleological and causal explanations (Kelemen et al., 2005). Others have distinguished between functional and mechanistic explanations (Lombrozo, 2010; Lombrozo & Wilkenfeld, 2018). These classification approaches share the same rationale: teleological-functional explanations are based on understanding functions, purposes, and meanings, reflecting the teleological mode of construal; causal-mechanistic explanations are based on understanding causal mechanisms or antecedents, reflecting the physical mode.

3.3.2 Children' s Evaluation and Adoption of Different Explanatory Modes Children' s explanatory questions involve many domains, and the answers they receive contain multiple modes. Children' s discrimination, evaluation, and adoption of different explanatory modes also concern selective causal learning research.

Discriminating between different explanatory modes first requires children to recognize and distinguish them. Children simultaneously possess both teleological-functional and causal-mechanistic modes of cognition (Keil, 1995). On one hand, middle-to-late elementary school children (ages 7-10) believe everything exists for a purpose, even using purposes or functions to understand properties of inanimate natural objects—for example, believing rocks are pointy to prevent animals from sitting on them and crushing them (Kelemen, 1999; see also Piaget, 1929; Schachner, Zhu, Li, & Kelemen, 2017). On the other hand, 3- and 4-year-olds believe spontaneous physical events must have causal antecedents—for instance, if a light bulb turned on by itself, it must be because the experimenter manipulated a hidden mechanism (Muentener & Schulz, 2014; Buchanan & Sobel, 2011). This indicates that children possess the cognitive

foundation to discriminate between different explanatory modes.

Based on this discrimination, do children show selective preferences for different explanatory modes? Naturalistic corpus analysis found that preschool children (ages 2-5) were more satisfied with explanatory answers from parents, showing more agreement and follow-up questions. However, preschoolers' follow-up responses to different explanatory modes did not differ significantly, suggesting no clear selective preference for any particular mode (Frazier et al., 2009). Other research found that 7- to 8-year-olds preferred teleological-functional explanations for biological questions and causal-mechanistic explanations for non-biological questions (Keil, 1992). Thus, developmental differences exist in children's evaluation of different explanatory modes: younger children show no selective preference for any mode, while older children begin to show mode-specific preferences based on domain-specificity of questions.

Children' s selective learning from others' testimony first manifests as discrimination or preference for testimony, and second as selective adoption. Memory for explanations can reflect children' s adoption of others' answers. For example, research found that 4- to 5-year-olds allocate more cognitive resources to processing explanatory answers, and their memory for answers relates to their satisfaction level, indicating that children' s retention of others' explanations reflects selective adoption of explanatory testimony (Frazier et al., 2016). Children' s generalization of others' explanations also reflects adoption of explanatory testimony. The natural pedagogy perspective suggests that children do not treat others' intentionally communicated knowledge as episode-specific but rather as generic knowledge (Csibra & Gergely, 2009), so children apply previously learned explanatory modes to similar problems.

A recent study directly examined preschoolers' adoption of others' explanations. The study presented 4- and 5-year-olds with natural phenomena (e.g., "stars are sparkly") accompanied by teleological-functional or causal-mechanistic explanations, then encouraged children to explain similar phenomena (e.g., "different kinds of stars are sparkly") and novel phenomena (e.g., "volcanoes emit gas"). Results showed that regardless of which explanatory mode children heard previously, most repeated the experimenter' s answers, with no significant differences in retention or transfer between the two modes. This indicates that preschoolers adopted different explanatory modes to the same degree, showing no preference for either type—that is, they indiscriminately accepted them all (Lombrozo, Bonawitz & Scalise, 2018). However, this study used a "single informant" paradigm (Vanderbilt, Heyman, & Liu, 2014; see also Jaswal, Carrington Croft, Setia, & Cole, 2010), where children received only one explanatory mode without alternative testimonies to remember or generalize. Future research could present children with both explanatory modes simultaneously to further investigate their selective adoption of different modes.

In summary, existing research shows that younger children exhibit no selective preference for different explanatory modes, while older children show mode-specific preferences under different domain questions. No research has exam-

ined older children' s selective adoption of different explanatory modes, and the only study with younger children has limitations, preventing unified conclusions from current findings. Indiscriminate learning of different explanatory modes has its rationality: it allows experience-poor children to master multiple explanations, providing diverse pathways for understanding. However, such non-selective learning also has drawbacks. Although both teleological-functional and causal-mechanistic explanations have explanatory and predictive functions, one mode may be more advantageous for understanding specific domain problems (Lombrozo & Wilkenfeld, 2018). Particularly when people have clear inferential purposes, the two explanations compete in evaluation (Lombrozo & Gwynne, 2014; Vasilyeva, Wilkenfeld, & Lombrozo, 2015). Therefore, children need to develop mature cognitive abilities to flexibly select and adopt appropriate explanatory testimony when facing different domain problems.

4 Summary and Future Directions

This article has systematically reviewed how explanation features—including verbal cues, structural characteristics, and modes—function in children' s discrimination, evaluation, and adoption of others' explanations. Younger children cannot yet distinguish appropriate explanations from multiple statements, but with age, they gradually differentiate valid explanatory statements from others' answers and identify high-quality explanations from multiple options. Children' s understanding and use of these cues and features reflect progressive cognitive development. However, several issues remain unresolved:

First, future research should further investigate the role of verbal cues in children' s selective causal learning. While verbal cues help people discriminate explanatory validity, they may also negatively affect explanation evaluation. For example, research shows that neuroscience terminology can distort adults' evaluation of explanations for psychological phenomena, making poor explanations seem acceptable—a phenomenon termed the "seductive allure" effect (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Follow-up studies found that explanation length or inclusion of brain localization information increased people' s quality assessments of explanations (Weisberg, Taylor, & Hopkins, 2015). This effect appears in many other disciplines, particularly those with strong reductionist thinking (Hopkins, Weisberg, & Taylor, 2016). One study examined the role of statement length in preschoolers' selective causal learning, finding that preschoolers were more satisfied with moderately long explanatory statements and showed better memory retention (Frazier et al., 2016). Researchers suggest that scientific terminology and statement length may serve as signals of expertise, leading people to blindly consider these markers of adequate explanation (Lombrozo, 2016). For children, when others' explanatory statements are overly complex or lengthy, these effects of verbal cues may distort children' s evaluation of others' testimony and even affect their selective learning from others' explanations. Future research on children' s selective causal learning should expand its focus on verbal cues, exploring how explanation comprehensibility influences

children' s discrimination and adoption of explanations.

Second, future research needs to examine the role of other explanation features, particularly content features, in children' s selective causal learning. On one hand, the influence of explanation features on judgment varies across contexts. Taking circularity as an example, some circular explanatory statements may be considered acceptable based on their content features. Research shows that people accept some circular explanations to a considerable degree (Prasada & Dillingham, 2006), such as "Why does she wear pink clothes?" "Because she is a girl." This explanation is circular, but people can recognize a meaningful connection between "wearing pink" and "being a girl," leading them to consider the explanation acceptable (see also Chin-Parker & Bradner, 2010). Such explanations essentially express Aristotle' s "formal cause" —justifying phenomenal properties through categorical relationships between explanatory elements and the object to be explained. In these cases, circular explanations point to formal causes, potentially leading people to consider them reasonable statements. Future research should examine children' s evaluation and selection of such formal explanations, which would not only deepen understanding of children' s selective causal learning but also illuminate children' s social categorical cognition (Prasada, 2017; see also Gelman, Cimpian, & Roberts, 2018; Sutherland & Cimpian, 2018). On the other hand, explanations have numerous virtues, such as coherence (the degree to which explanation content aligns logically with surrounding statements, existing knowledge, or objective evidence) and completeness (the degree to which explanation content lacks omissions) (Glymour, 2015; Keil, 2006; Zemla, Sloman, Bechlivanidis, & Lagnado, 2017). However, current research on how explanatory quality affects children' s selective causal learning has focused mainly on structural features like simplicity and breadth. Examining only structural features is limited; future research should further investigate how content features of explanations affect children' s selective causal learning.

Third, current conclusions about the domain-specificity of explanatory modes are inconsistent. Explanations are domain-specific, with different features across domains (Keil, 2006). Research shows that young children spontaneously generate different explanatory modes and demonstrate domain-specific characteristics (Sanchez Tapia, Gelman, Hollander, Manczak, Mannheim, & Escalante, 2016; see also Hickling & Wellman, 2001; Keil, 1992). However, other findings contradict this: 2- to 5-year-olds showed no different follow-up responses to different explanatory modes provided by parents (Frazier et al., 2009), and their transfer effects across different modes were similar (Lombrozo et al., 2018). These results support the domain-generality of explanatory modes, but their conclusions have limitations. Frazier et al. (2009) did not examine children' s evaluation of explanations separately by question domain, only investigating children's follow-up responses to different explanations overall. Lombrozo et al. (2018) did not exclude the influence of children' s prior explanatory mode preferences when examining their retention and transfer of different explanatory modes, selecting problem domains where children had spontaneous explanatory biases. Future

research could select domains where children have no prior explanatory mode preferences, such as dynamic properties of animals and artifacts (behaviors or movements) (Sanchez Tapia et al., 2016), as research materials. Additionally, future studies should treat question domain as a variable, examining children' s selective learning of different explanatory modes across domains to further explore the domain-generality versus domain-specificity of explanatory modes.

Fourth, subsequent research should further investigate the cognitive developmental mechanisms underlying children' s selective learning from others' explanatory testimony. On one hand, adults' preference for simple explanations is based on rational judgment, stemming from simple explanations' unique role in prediction and control (Pacer & Lombrozo, 2017). However, whether children' s preferences for simple and broad explanations are based on heuristic judgment or rational judgment considering explanatory predictive power (e.g., Hermes et al., 2018) remains to be explored. On the other hand, developmental differences exist in children' s discrimination and adoption of different explanatory modes, yet current research lacks investigation of their mechanisms. For example, developmental changes in children' s selective causal learning may result from the gradual maturation of their effective questioning abilities. Questions posed by 3- to 5-year-olds are often ambiguous (e.g., "Why is it like this?"), but with age, children' s questions become increasingly specific and effective (Ruggeri & Lombrozo, 2015; Ruggeri, Lombrozo, Griffiths, & Xu, 2016). By ages 11 and 12, children can already ask clear causal-mechanistic questions (Luce & Hsi, 2015). Questioning aims to effectively acquire information and reflects expectations about the scope of answers (Harris, 2012; Ronfard, Zambrana et al., 2018). Future researchers need to examine the relationship between children' s effective questioning abilities and selective learning, revealing the role of cognitive ability development in selective causal learning.

In conclusion, investigating the cognitive developmental mechanisms of children' s selective causal learning will help deepen understanding of children' s cognitive abilities and their developmental potential, revealing the origins of individuals' capacity to acquire knowledge through external resources.

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Children' s Selective Learning in the Domain of Causal Knowledge

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Abstract: In recent years, children's selective learning has attracted widespread attention in the field of cognitive development. Specifically, understanding children' s selective learning in the domain of causal knowledge provides important insights for addressing a classic question in developmental research: how children acquire knowledge. Children generally acquire causal knowledge by identifying, evaluating, and endorsing information from others. They actively seek explanations from reliable informants and select their responses based on the quality of the answers they receive. Even from an early age, children can use verbal cues to distinguish explanatory responses from non-explanatory responses. Moreover, when given several explanations, they can tell which one is superior based on the structural characteristics of these explanations. Older children can even identify various modes of construal and adopt the appropriate one. Future studies could further investigate the roles of other explanatory characteristics in children' s selective causal learning and address controversial issues regarding the cognitive mechanisms of selective causal learning.

Keywords: selective learning; causal knowledge; explanation-seeking; explanatory qualities/virtues; modes of construal

Note: Figure translations are in progress. See original paper for figures.