Mind the gap: How incomplete explanations influence children’s interest and learning behaviors

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ARTICLE INFO

Keywords:
Explanation evaluation
Information deprivation
Interest
Learning behaviors

ABSTRACT

Children rely on others’ explanations to learn scientific concepts, yet sometimes the explanations they receive are incomplete. Three studies explore how receiving incomplete or complete explanations influences children’s subsequent interest and engagement in learning behaviors to obtain additional information about a topic. Children ages 7–10 (N = 275; 49% female, 51% male; 55% white) viewed question-and-answer exchanges about animal behaviors that included either a complete causal explanation of the behavior or an explanation that was missing a key step. Children rated how knowledgeable they felt after hearing the explanation (Study 1) or how much information was missing from the explanation (Studies 2 and 3) and reported how interested they were in learning more about the topic. They also completed two measures of learning behaviors: a book choice task (all studies) and a card choice task (Studies 1 and 2). In the book choice task, children opted to learn about the topics of the incomplete explanations more frequently than the topics of the complete explanations. However, there was no evidence of selective learning behaviors in the card choice task and children’s self-reported interest in learning more about each animal behavior was not directly related to the type of explanation they had received. Individual differences in children’s interest and learning behaviors were linked to verbal intelligence and domain-specific biological knowledge. Implications for the information-gap theory of learning and children’s learning in multiple contexts are discussed.

1. Introduction

Causal explanations, or statements that explain why or how an event occurred, are essential for developing an understanding of the world (Keil, 2011; Lombrozo, 2006, 2011; Wellman, 2011). However, causal explanations do more than simply answer questions; they also serve a crucial role in the learning process by constraining causal inferences (Walker et al., 2017) and providing insights that are helpful for problem solving (Crowley & Siegler, 1999; Lombrozo, 2006). Young children can learn from and generalize causal explanations to new exemplars (Legare & Lombrozo, 2014; Lombrozo et al., 2018) and they can potentially use explanations to guide hypothesis testing (Legare, 2014) and analogical reasoning (Goddu et al., 2020). Given the multi-faceted benefits of causal explanations for learning (Kelemen, 2019), it is not surprising that both adults and children value causal explanations over simpler forms of evidence (Kuhn, 2001).
The benefits of receiving coherent causal explanations are clear, yet the quality of the explanations that children receive from adults varies widely (e.g., Corriveau & Kurkul, 2017; Tizard & Hughes, 1984). Sometimes children receive answers to their questions that accurately and completely explain a phenomenon, yet other times children receive explanations that are incomplete or uninformative. Although the content of incomplete explanations may not fully support children’s learning, receiving weak explanations may play an important role in motivating children’s learning. For instance, receiving a circular or uninformative explanation can provoke children to ask follow-up questions (Chouinard, 2007; Frazier et al., 2009) or to seek out additional information on their own (Mills et al., 2017, 2019). The current studies examine how receiving incomplete explanations - explanations that provide some information but that are missing a key component - relates to children’s subsequent interest in learning and engagement in learning behaviors. Incomplete explanations may be more challenging for children to evaluate than circular or uninformative explanations and they may have different effects on children’s interest and motivation. We also explore potential sources of individual differences in children’s explanation evaluation and their subsequent learning behaviors.

1.1. How explanation evaluation motivates learning

Children are sensitive to the quality of explanations, and they are most satisfied by explanations that are simple and broad (Lombrozo, 2016) or that provide a moderate level of detail (Frazier et al., 2016). By age 6, children also show dissatisfaction with arguments or explanations that are structurally flawed, such as logically inconsistent statements (Doebel et al., 2016; Morris & Hasson, 2010; Ruffman, 1999) and circular explanations (Baum, Danovitch, & Keil, 2008; Corriveau & Kurkul, 2014). However, in these studies, children typically heard contrasting pairs of statements about the same topic (e.g., a circular explanation paired with a noncircular explanation) before choosing the best answer or informant. In reality, children are more likely to encounter single explanations that they must evaluate without a comparison to a weaker or stronger alternative. Evaluating single explanations is more challenging than comparing explanations (Mills et al., 2017), yet doing so effectively has potential benefits for learning.

After children realize that an explanation is flawed or missing information, they must decide whether they have received sufficient information to support their understanding or whether they should take further action to fill the gaps. According to the information-gap theory (Golman & Loewenstein, 2018; Loewenstein, 1994), recognizing that there is a gap in a causal explanation should result in a feeling of deprivation that stimulates curiosity and motivates engagement in further learning. Similarly, Keil (2006) proposes that when individuals encounter an explanatory gap, they either suppress their feeling of ignorance or attempt to fill the gap. Supporting these proposals, there is evidence that children take actions to address gaps in their knowledge and understanding beginning early in life. Toddlers engage in specific non-verbal behaviors (e.g., pointing) to fill knowledge gaps, and by age 2–3 children use both verbal means (e.g., asking questions) and nonverbal means of filling gaps (Harris et al., 2017). By age 5 or 6, children also recognize that it is sometimes important to ask another person for help solving a problem as opposed to trying to solve it on their own, although their ability to do so depends greatly on the domain (Aguiar et al., 2012; Fitneva et al., 2013; Rowles & Mills, 2018).

Two sets of studies including children ages 7–10 have also demonstrated a link between children’s ability to recognize weak explanations and their subsequent engagement in learning behaviors. In Mills et al., 2017, children who recognized that they had heard circular explanations about unfamiliar animal behaviors during a laboratory session took home more cards containing facts about the animals at the end of the session. A second study using a self-directed exploration task found that children were more likely to seek out additional information about an animal behavior after hearing a circular explanation than a noncircular one (Mills et al., 2019). Thus, children who recognized that their understanding of a topic remained incomplete after hearing an answer to a question were more likely to take action to obtain the missing information. Notably, in both studies, there was variability in children’s explanation evaluation and in their engagement in additional learning, and this variability could not be explained solely in terms of age or verbal intelligence.

1.2. The role of existing knowledge and cognitive characteristics

Recognizing that an explanation is incomplete can drive children’s interest in further learning, yet several factors may influence how effectively an individual child evaluates explanations, and how motivated they are to obtain information after hearing a weak explanation. Adults show individual differences in explanation evaluation, such that some adults prefer detailed mechanistic explanations of how a device works and others prefer shallow, surface-level explanations (Fernbach et al., 2013). As early as during preschool, children also display individual differences in their interest in causal information (Alvarez & Booth, 2016; Booth et al., 2020) and their degree of curiosity in response to the same experiences (Henderson & Moore, 1980). That said, the factors that contribute to individual differences in curiosity are understudied, particularly in children (Silvia, 2012). Moreover, like adults, children may show variability in their reactions to causal explanations that may affect their subsequent motivation to learn. Here we explore several potential cognitive influences on children’s recognition of explanatory gaps and their interest in further learning.

The first potential influence we explore is domain-specific knowledge. Domain-specific knowledge may provide a foundation for children’s question-asking and explanation evaluation (Ronfard et al., 2018). For example, children who know more about biology may be able to build on their prior understanding of biological mechanisms to recognize when an explanation of a novel biological process is missing a key component. Domain-specific knowledge might also influence how children react to hearing an incomplete explanation. Children who have more background knowledge about a topic may find an incomplete explanation more surprising or jarring, and they may consequently experience an increased drive to fill the gap in their knowledge (Markey & Loewenstein, 2014). Thus, children with more domain-specific knowledge might be more motivated than children with less domain-specific knowledge to acquire information that will fill the gaps in their understanding. Existing domain-specific knowledge might also reflect children’s
broaden interest in learning. For instance, children who know more about biology may already be more interested in animals and consequently be more motivated to learn about unfamiliar animal behaviors than children who know less about biology.

In addition to domain-specific knowledge, children’s explanation evaluation and learning behaviors may be influenced by domain-general verbal knowledge and executive function skills. Verbal intelligence has been linked to children’s recognition of weak explanations and information-seeking behavior (Mills et al., 2017). Children’s receptive vocabularies predict listening comprehension (Kim, 2015); thus, children with stronger vocabularies may be better able to comprehend multi-step explanations and recognize when something is missing. Executive function has been linked to young children’s understanding of new scientific information (Bascandiev et al., 2016; Tardiff et al., 2020) and their ability to detect illogical statements (Doebel et al., 2016). Moreover, in a study controlling for age and verbal IQ, better working memory and stronger inhibitory control predicted more sophisticated biological reasoning among 5- to 7-year-olds (Zaitchik et al., 2014). These findings suggest that children with stronger executive function skills might also be better at recognizing gaps in causal sequences. Thus, the current studies explore how variability in children’s verbal intelligence, working memory, and inhibitory control relate to their ability to recognize and respond to incomplete biological explanations and their subsequent decisions about further learning.

1.3. Study design

The current studies focus on explanation evaluation and learning behaviors among children ages 7–10 as this is a time when children’s ability to evaluate single explanations (i.e., explanations not presented in direct contrast to a stronger or weaker explanation) is developing and improving (Mills et al., 2017). Children in this age range are also becoming more aware of the limitations of their own knowledge and understanding (Mills & Keil, 2004) and more adept at searching for information on their own (e.g., Druin et al., 2009; Duarte Torres et al., 2014). As they gain more experience with formal education, children are also more likely to encounter complex explanations and to have to make decisions about how to proceed when their understanding is incomplete.

In order to explore children’s reasoning about complex concepts, the current study involves biological explanations. Biology is a causally rich domain where there can be strong, iterative causal explanations. Children experience biological processes first-hand and they show a natural interest in animals (Inagaki & Hatano, 2006; LoBue et al., 2013) – the focus of the questions and explanations in the current study. Because elementary school children perceive biology as a relatively difficult domain of knowledge (Keil et al., 2010) and both children and adults hold misconceptions about biological explanations (Colev, Tanner, & Sevian, 2015), understanding the processes underlying children’s learning behaviors in response to biological explanations can provide insights into broader scientific learning.

Our methods and analyses were designed to address multiple questions. First, extending prior work on children’s evaluation of single circular explanations (e.g., Mills et al., 2017), we examined children’s evaluations of single complete and incomplete biological explanations. We predicted that, with age, children would be more aware of gaps in their understanding of the topic after hearing an incomplete explanation. Second, we were interested in how explanation evaluation related to children’s interest in learning more about the topic of each explanation, measured through both self-report and engagement in learning behaviors. We expected that children who felt they knew less after hearing incomplete explanations than complete explanations would express greater interest in learning more about the topic. Third, we examined the relative contributions of age, biological knowledge, verbal intelligence, and executive function to explanation evaluation and subsequent engagement in learning behaviors, with an expectation that children who were more knowledgeable and had stronger executive function skills would be more sensitive to information gaps and more motivated to fill these gaps through their learning behaviors.

2. Study 1

2.1. Methods

2.1.1. Participants

Participants included 44 7- to 8-year-old children (20 males and 24 females; Mage = 7.96, range = 7.00–8.99) and 47 9- to 10-year-olds children (25 males and 22 females; Mage = 9.86, range = 9.05–10.99). A power analysis was conducted using G*Power 3.1 based on the effect size from the explanation rating tasks in Mills et al. (2017, Experiment 1) and moderately conservative settings otherwise. This analysis suggested that an appropriate sample size would be 40 children per age group.

Approximately equal numbers of children were recruited from the Louisville, Kentucky and Dallas, Texas areas using lab databases, social media advertisements, and university-based research credit websites. Children were primarily white and non-Hispanic. (See supplemental materials for detailed information about race, ethnicity, family income, and parent education.) Families received financial compensation for participation. Children were interviewed individually for approximately 90 min by a female experimenter in a lab setting and completed the measures described below, as well as additional exploratory measures not reported here.

2.1.2. Materials and procedure

Explanation Evaluation and Information Seeking Measures. Following several rounds of development and piloting (see supplemental materials for details), we identified a set of 10 animal behaviors for which the majority of pilot participants were unable to accurately fill the gap in each explanation and for which they felt relatively uncertain about their responses. We then grouped the items into 5 pairs such that each pair included different types of behaviors (e.g., hunting prey, escaping predators) and categories of animals (e.g., birds, aquatic animals).
Introduction and Practice Items. Children were told that they were going to play a game about animals and that the experimenter’s friend “Jane” was going to ask some questions about animals and another person would answer her questions.

Children then completed two practice items using unfamiliar objects (a zoetrope and a phonograph) for which they heard a complete or a circular explanation, completed the check question, and rated their knowledge after hearing the explanation. If children rated themselves as having very little knowledge after the complete explanation, they were reminded that the scale was intended to reflect their knowledge after hearing an explanation.

Explanation Presentation. All explanation evaluation measures were presented on a laptop computer using Microsoft PowerPoint software. In each trial, children viewed a black and white drawing corresponding to the animal behavior but not including the mechanism of interest (e.g., a drawing depicting a badger looking into a tunnel with a squirrel in it) in the center of the screen, with two female stick figures corresponding to “Jane” and her friend on each side of the screen. (See Appendix A for complete list of behaviors.) A speech bubble appeared above the figure on the left (Jane) and children heard an audio recording approximately 12 s long of the initial prompt, ending with Jane’s question (e.g., Badgers like to eat squirrels but the squirrels hide from them in small tunnels underground. How do some badgers catch squirrels that hide in small tunnels underground?). Then a speech bubble appeared above the
character on the right and children heard Jane’s friend’s initial answer, which provided a causal explanation that was missing a key middle step (e.g., The badgers find underground tunnels with squirrels in them. Next, they get some soil from the area near the tunnels. Then, the badgers can catch the squirrels and eat them.). Jane then asked a probing question about the mechanism, highlighting the gap in the explanation (e.g., How does getting soil from the area near the tunnels help the badgers catch the squirrels and eat them?). For complete explanations, this probing question was followed by a statement by Jane’s friend that completed the explanation by describing the missing step (e.g., The badgers trap the squirrels by blocking all of the tunnel entrances with soil except for one.) For incomplete explanations, Jane’s friend responded by stating that she did not know (e.g., I don’t know how getting soil from the area near the tunnels helps the badgers catch the squirrels and eat them.) See Fig. 1 for an overview of the explanation evaluation task.

Following each question-and-answer exchange, children responded to three prompts related to the animal behavior: an attention check question, knowledge rating, and interest rating.

**Attention Check.** After hearing Jane’s probing question and her friend’s response, children were asked, “Did Jane’s friend explain [animal behavior] or did she say she didn’t know?”

**Knowledge Rating.** After answering the attention check question, children rated their knowledge using a 5-point scale. Children were asked: “You’ve heard some things about [animal behavior]. How much of that information do you think you know right now?” Children viewed 5 circles whose interiors contained progressively larger amounts of color, and they were told that the circles corresponded to how much there is to know about something such that the least-filled circle corresponded to “knowing almost nothing” and the most-filled circle corresponded to “knowing almost everything there is to know about something.” Children indicated their responses by pointing to one of the circles.

**Interest Rating.** Children were asked, “How much would you like to learn about [animal behavior]?” Children indicated their interest using a 5-point scale where the points of the scale were cartoon faces ranging from a bored face to a smiling face with the words “not at all,” “a little,” “sort of,” “very,” and “extremely” underneath the corresponding faces.

**Book Choice.** After hearing a question-and-answer exchange and responding to prompts for one complete item and one incomplete item, children completed a book choice task for the animal behaviors in those two items. Children viewed drawings of two identical books with the name of one animal from the preceding pair on each cover (e.g., badgers and sea otters) and were told: “You are going to get a chance to hear some books about these animals. The books will teach you more about them. Would you rather hear a book about [animal 1] or [animal 2]?” After indicating their preference, children proceeded to the next pair of question-and-answer exchanges and explanation ratings. (The selected books were not presented during the session.)

**Card Choice.** The card choice task was modeled after Mills et al., 2017. Following all 5 pairs of explanations and book choice trials, the experimenter put away the computer and brought out 10 full color 2.5” by 3.5” animal fact cards and laid them in random order on the table. The experimenter explained that there was a picture of each animal from the study on the front of each card, and facts about the animal on the back. Children were told that they could take as many or as few animal cards home as they wanted and they were given an envelope in which to place their cards. The experimenter then turned away while the child chose their cards, and the experimenter secretly noted which cards had been chosen. The envelope was put aside until the end of the session, when children received all of the cards.

**Presentation Order.** The type of explanation associated with each animal behavior was balanced across participants, such that half of participants heard an incomplete explanation for a specific animal behavior and the other half heard a complete explanation for that behavior. Animal pairs were also presented in one of two random orders, yielding 4 different presentation orders that were evenly distributed across age groups.

### 2.1.3. Individual differences measures

**Verbal Intelligence.** Children completed the verbal portion of the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2004), which includes receptive vocabulary and semantic knowledge. Raw scores were converted to standardized scores.

**Biological Knowledge.** In order to measure children’s existing knowledge about biological processes, we developed a new 15 item measure (see supplemental materials). Questions were drawn from the 2007 and 2011 editions of the Trends in International Mathematics and Science Study (TIMSS) and were intended to represent a wide range of difficulty based on the percentage of correct responses reported for American 4th graders. Item topics included animal survival mechanisms, lifecycles, and adaptations. Items were presented individually on a laptop screen and read out loud. Thirteen items were multiple choice, and two items involved brief open-ended responses. Total scores could range from 0 to 15.

**Inhibitory Control and Attention measure.** Using the NIH toolbox iPad application, children completed the Flanker task (adapted from Eriksen & Eriksen, 1974) as a measure of inhibitory control and attention. The NIH Toolbox software provided age-standardized scores.

**Working Memory measure.** Children completed the working memory subscale from the WISC-V (Wechsler, 2014), yielding a scaled score of 1–19.

### 2.2. Results

#### 2.2.1. Explanation evaluation

Preliminary analyses showed no effect of gender or item order so these variables were excluded from further analysis.

**Attention Check.** Participants responded accurately to 95% of the check questions (92% for the incomplete items and 98% for the complete items). All participants answered 7 or more check questions correctly, except for two 7-year-old children (both ages 7;0) who
answered only 5 check questions correctly. Removing these two children did not significantly change the pattern of results; thus, they were retained in the analyses. **Knowledge Ratings.** A repeated measures 2 (Age group: 7–8 or 9–10) X 2 (Item type: complete or incomplete) ANOVA for average knowledge ratings revealed a main effect of item type, $F(1, 87) = 59.40, p < .001$, partial $\eta^2 = 0.285$. As predicted, children rated their knowledge lower for incomplete ($M = 2.86, SD = 1.06$) than complete items ($M = 3.46, SD = 1.08$; see **Table 1**). Ratings for complete items also significantly differed from the midpoint of the scale, $t(90) = 4.078, p < .001$, but ratings for incomplete items did not, $t(90) = 1.272, p = .207$. There were no other significant main effects nor interactions, $F$s < 2.373, $p$s > 0.127. (See Table S1 for means and SDs by age group and item type.)

### 2.2.2. Interest and learning behavior measures

**Interest Ratings.** A repeated measures 2 (Age group: 7–8 or 9–10) X 2 (Item type: complete or incomplete) ANOVA for interest ratings revealed no significant main effects nor significant interactions, all $F$s < 3.054, $p$s > 0.084. Overall, children indicated strong interest in learning more about both incomplete ($M = 3.82, SD = 0.83$) and complete items ($M = 3.68, SD = 0.87$), and their interest ratings for both types of items were significantly higher than the midpoint of the scale, $t$s > 7.513, $p$s < 0.001 (see **Table 1** and Table S1).

**Learning Behaviors: Book Choice.** Children chose books corresponding to the incomplete items in 58% of trials (range = 0 to 100%), a rate significantly higher than chance, $t(90) = 3.067, p = .003$. There was no significant difference between age groups in rates of choosing the incomplete item books, $t(89) = 0.493, p = .695$. (See Table S1 for means by age group.)

**Learning Behaviors: Card Choice.** On average, children chose to take home 6.18 cards out of the 10 animal cards (range = 0 to 10 cards; modes: 5 and 10 cards). A repeated measures 2 (Age group: 7–8 or 9–10) X 2 (Card type: complete or incomplete) ANOVA revealed no significant main effects of age group or card type, all $F$s < 2.490, $p$s > 0.118

### 2.2.3. Predictors of individual differences in knowledge, interest, and learning behaviors

In order to better understand the factors underlying individual differences in children’s engagement in learning behaviors, the following analyses focus on identifying predictors of children’s knowledge and interest ratings and decisions in the book and card choice tasks. Preliminary analyses suggested no effects of age (treated continuously), gender, or item order on children’s explanation evaluations, interest ratings, and learning behaviors so these variables were excluded from further analyses. Descriptive information for all outcome measures and predictors are provided in **Table 1**. Because of the large number of correlations that were computed, the Benjamini-Hochberg procedure was used to reduce Type I error (Benjamini & Hochberg, 1995), with the false discovery rate set to $q = 0.05$. For all regression analyses, the data met assumptions of normality and linearity, and contained no multicollinearity between predictors.

**Knowledge Ratings.** Children’s mean knowledge ratings for the incomplete items were significantly negatively correlated with biological knowledge scores, verbal intelligence, and working memory (see **Table 1**). In contrast, there were no significant correlations between knowledge ratings for the complete items and any of the cognitive measures. Thus, children who rated their knowledge lower after hearing incomplete explanations tended to perform better on measures of domain-general and domain-specific background

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### Table 1

**Correlation Matrix for all Primary Study Variables in Study 1.**

|   | 1. Exact age | 2. Knowledge: incomplete | 3. Knowledge: complete | 4. Interest: incomplete | 5. Interest: complete | 6. Book choice (proportion) | 7. Card choice (total taken) | 8. Biological knowledge | 9. KBIT-2 score (n = 90) | 10. Working Memory | 11. Inhibition (n = 86) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Exact age | $M = 8.94$ | $SD = 1.14$ | -0.09 | 0.00 | 0.02 | -0.10 | 0.00 | -0.17 | 0.38*** | 0.01 | 0.15 | 0.20 |
| 2. Knowledge: incomplete | 2.86 | 1.06 | -0.60*** | 0.22* | 0.33** | -0.22* | -0.13 | -0.31** | -0.42*** | -0.35** | -0.06 |
| 3. Knowledge: complete | 3.46 | 1.08 | – | 0.27* | 0.24* | 0.06 | 0.05 | -0.13 (-0.20) | -0.18 | -0.18 | -0.01 |
| 4. Interest: incomplete | 3.82 | 0.83 | – | 0.63*** | 0.24* | 0.17 | -0.14 (-0.12) | -0.20 | -0.17 | -0.06 |
| 5. Interest: complete | 3.68 | 0.87 | – | -0.21* | 0.22* | -0.34** | -0.34** | -0.32** | -0.20 | 0.00 |
| 6. Book choice (proportion) | 0.58 | 0.25 | – | 0.14 | 0.22* | (0.28*) | 0.29** | 0.16 | -0.05 |
| 7. Card choice (total taken) | 6.18 | 2.52 | – | 0.12 (0.17) | 0.13 | 0.05 | 0.00 |
| 8. Biological knowledge | 9.13 | 2.75 | – | 0.59*** | 0.65*** | 0.44*** | 0.19 | (0.23) |
| 9. KBIT-2 score (n = 90) | 106.49 | 15.48 | – | – | 0.53*** | – | 0.12 |
| 10. Working Memory | 10.47 | 3.08 | – | – | – | – | 0.12 |
| 11. Inhibition (n = 86) | 96.51 | 12.65 | – | – | – | – | – |

### Note.

Correlations controlling for exact age are reported in parentheses for biological knowledge measure. Bold font indicates values that remained significant after the Benjamini-Hochberg correction ($q = 0.05$). $N = 91$ unless otherwise noted.

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* $p < .05$. ** $p < .01$. *** $p < .001$. 

knowledge as well as working memory; no such relation was present for ratings of complete explanations.

To examine how much of the total variance in each type of knowledge rating was accounted for by children’s verbal intelligence, biological knowledge, and working memory, a hierarchical multiple regression was conducted with knowledge ratings for the incomplete items entered as the dependent variable. (Note that inhibition was excluded from these and all subsequent regression analyses as it was not correlated with any of the key outcome variables; see Table 1.) Based on evidence that children’s ratings of their own knowledge are inversely related to verbal intelligence (Danovitch et al., 2019), and given the verbal complexity of the explanation evaluation task, KBIT-2 scores, which reflect verbal intelligence, were entered in the first step as a control variable and biological knowledge and working memory scores were entered together in the second step (see Table S2). Age was also entered in Step 1, as it related to biological knowledge.

When entered in Step 1, Age and KBIT-2 scores accounted for 18.1% of the variance in knowledge ratings for incomplete items, $F$ change $(2, 87) = 9.597, p < .001$. After entering the additional predictors, the amount of variance explained by the model increased to 20.1%, $F$ change $(2, 85) = 1.077, p = .345$. The only predictor in the final model that was significantly related to knowledge ratings for incomplete items was KBIT-2 score ($B = -0.021, p = .026$). Thus, higher verbal intelligence was associated with lower ratings of knowledge after receiving incomplete explanations.

**Interest Ratings.** Interest ratings for the incomplete items were significantly correlated with knowledge ratings for complete items, and interest ratings for complete items were significantly correlated with knowledge ratings for incomplete items (see Table 1). Thus, the more knowledgeable children felt after hearing incomplete explanations, the more interest they reported in learning about the complete items, and vice versa. In other words, greater knowledge for one type of item related to greater interest in the other type of item.

As shown in Table 1, interest ratings for incomplete items were not significantly correlated with any of the individual difference measures. There were, however, significant correlations between interest ratings for complete items and KBIT-2 scores, $r(87) = 0.321$, $p = .002$, as well as biological knowledge scores (controlling for age), $r(88) = -0.324$, $p = .002$. However, neither knowledge measure was a significant predictor of interest ratings after accounting for knowledge rating and age (see Table S3 for regression analysis).

**Book Choice.** As shown in Table 1, children’s knowledge and interest ratings following the complete and incomplete explanations were not significantly correlated with their book choices following the Benjamini-Hochberg correction for multiple correlations. There was, however, a significant correlation between book choice and KBIT-2 scores, $r(91) = 0.270, p = .010$, such that children with higher verbal intelligence were more likely to select the books corresponding to the incomplete items.

A hierarchical multiple regression was used to assess how effectively the verbal intelligence and biological knowledge measures predicted the proportion of trials in which children chose the incomplete item books. Age, knowledge ratings, and interest ratings for the incomplete items were entered in Step 1, explaining 13.9% of the variance, $F$ change $(3, 86) = 4.631, p = .005$ (see Table S4). After entry of the individual difference variables in Step 2, the total variance explained by the model was 20.1%, $F$ change $(2, 84) = 3.259, p = .043$. In the final model, interest ratings for the incomplete items were the only significant predictor of book choice, $B = 0.102, p = .001$.

Multilevel modeling was used to further explore whether children’s ratings of their knowledge for each animal item influenced their book choices, and specifically whether children who rated their knowledge lower for the incomplete item than for the complete item in each pair were more likely to choose the book about that animal. First, we calculated a child-centered knowledge rating for each item by subtracting the mean of their knowledge ratings for all 10 items from their knowledge rating for each item. Then we calculated the difference in the child-centered knowledge ratings between complete and incomplete items in each pair of animals, such that higher difference scores corresponded to rating knowledge higher for complete than incomplete items. Using SPSS, we created a generalized linear multilevel model that included participants (to account for participant variation) and the difference between knowledge ratings (to account for variability in the relation between the child’s knowledge ratings and their book choices) as random effects. The reference category was set such that the results indicate how increases in the child-centered difference relate to selection of the incomplete item book. The results suggested that there was no significant relation between the difference in child-centered knowledge ratings for individual items in each pair and children’s subsequent choice of book, $B = 0.029, SE = 0.086, OR = 0.972, 95% CI = [0.821, 1.15], p = .738$.

We followed the same procedure to analyze the relation between interest ratings for each item in an animal pair and choice of the incomplete item book. Note that, to make the findings easier to interpret, we calculated the differences between ratings by subtracting the complete item rating from the incomplete item rating such that positive difference scores indicate greater interest in the incomplete than the complete item, and negative difference scores indicate greater interest in the complete than the incomplete item. The results showed a significant relation between the difference in children’s interest ratings for each item and choice of the book corresponding to the incomplete item, $B = -0.806, SE = 0.118, OR = 0.447, 95% CI = [0.353, 0.565], p < .001$. The odds ratio indicated that for every 1 point increase in the difference between interest ratings for the complete and incomplete items (corresponding to relatively higher interest in the incomplete item than the complete item), children were 55% more likely to choose the book corresponding to the incomplete item. Thus, children who rated their interest in the incomplete item highly relative to their interest in the complete item in each pair were more likely to choose the book corresponding to the incomplete item.

**Card Choice.** There were no significant correlations between the number of cards taken and knowledge or interest ratings for each type of item. Multilevel modeling using child-centered knowledge and interest ratings to predict the likelihood of taking home a given card also found no relation between knowledge ratings and card choice, $B = 0.029, SE = 0.086, OR = 0.972, 95% CI = [0.821, 1.15], p = .738$. There was a significant positive relation between interest ratings for each animal and children’s decision to take home the corresponding animal card, $B = 0.553, SE = 0.0889, OR = 1.739, 95% CI = [1.461, 2.071], p < .001$. For every one-unit increase in interest rating in an animal, children were 74% more likely to take home the corresponding card. Thus, children’s decisions about taking home specific cards were more closely tied to their self-reported interest in learning about the animal than to their assessment of
their knowledge about the animal's behavior.

2.3. Discussion

Broadly, Study 1 examined whether exposure to explanatory gaps would lead to interest in filling those gaps, as evidenced by self-report or actual learning behaviors. Across age groups, children recognized that they knew less after hearing an incomplete explanation about an animal's behavior than after hearing a complete explanation. Children who rated their knowledge higher for either explanation type reported more interest in learning about items corresponding to the other type of explanation than children who rated their knowledge lower. Although these findings do not directly support our hypothesis that children who felt less knowledgeable after hearing an incomplete explanation would report being more interested in learning about that topic, they provide indirect evidence that children's interest in learning is related to the explanations they receive. Perhaps feeling knowledgeable about one topic prompted children to be more interested in the other topic simply as a function of believing there was more left to learn about the other topic or finding the other topic more novel.

Although the positive correlations between knowledge and interest ratings for each type of item were not significant after the Benjamini-Hochberg correction, this pattern of results contradicted our hypothesis that children who recognized that they were not as knowledgeable after hearing an incomplete explanation would report being more interested in that topic. One potential explanation for this surprising pattern is that children who know about animals, or who at least believe that they know about animals, may be more interested in learning about animals than children who know less. Children’s self-reported interest in animals may even predate the experience of hearing the incomplete and complete explanations in the study. However, the negative correlation between children's knowledge ratings for incomplete items and scores on the biological knowledge measure does not support this possibility. Instead, perhaps children who have less background knowledge about biology are less sensitive to the gaps in their knowledge and therefore rate their knowledge higher after both types of explanations, yet they still feel an implicit interest in learning. Or perhaps children’s view of their own knowledge and their interest in learning are relatively disconnected, such that reporting interest in a topic is not directly tied to the experience of a knowledge gap.

In addition, the results suggest that hearing incomplete explanations influenced children’s learning behaviors in the book choice task, but not the card choice task. Across all items, children chose incomplete item books more often than complete item books. Although, children’s frequency of choosing the incomplete item books was not correlated with knowledge or interest ratings, multilevel modeling suggests that interest ratings were predictive of choosing incomplete item books for specific animal pairs. A similar relation existed for the card choice task, where children’s choice to take home a specific animal card was related to their interest rating for that card, but not to their knowledge rating. These findings suggest that interest may be driving children’s learning behaviors more than an awareness that they are lacking information and that children’s self-reported interest serves as a relatively accurate predictor of their likelihood of engaging in behaviors to learn more about a topic.

Children’s preference for the incomplete item books in the book choice task also suggests that when children face situations where their exploration is restricted (i.e., they can only choose to hear one of two books), they may prioritize obtaining information to fill gaps in their knowledge. But when exploration is not restricted (i.e., they can take home as many cards as they want), children engage in broader learning behaviors that may be driven by multiple factors, including their interest in the topic. Study 2 addresses this possibility by restricting children’s exploration for both learning behavior tasks.

In addition to describing children’s responses to incomplete and complete explanations in general, Study 1 was designed to explore the predictors of individual differences in children’s explanation evaluation, interest, and learning behaviors. Notably, younger and older children seemed to approach these tasks in similar ways and their knowledge ratings, interest ratings, and engagement in learning behaviors did not vary by age. There was also no evidence that inhibition played a role in children’s behaviors. However, verbal intelligence, biological knowledge, and working memory were somewhat predictive of children’s ratings and learning behaviors. Children with higher verbal intelligence and higher biological knowledge scores, as well as stronger working memory, rated their own knowledge lower after hearing incomplete, but not complete, explanations. This finding aligns with prior work suggesting that children with higher intelligence scores are more conservative (and, thus, more realistic) than children with lower intelligence scores when rating their own knowledge (Danovitch et al., 2019). Children with higher scores on the biological knowledge and verbal intelligence measures also expressed less interest in learning after complete explanations than children with lower scores, suggesting that their prior knowledge may have influenced their interest ratings. That said, after factoring in age and interest ratings, neither verbal intelligence, biological knowledge, nor working memory were predictive of children’s learning behaviors in the book and card choice tasks. Although some cognitive factors related to children’s explicit judgments about their knowledge and interest in a topic, children’s engagement in learning behaviors appeared to be relatively independent of their judgments about the information at hand.

3. Study 2

The information-gap theory of learning (Golman & Loewenstein, 2018; Loewenstein, 1994) proposes that feelings of deprivation drive information-seeking behaviors. Although children recognized that there were gaps in some of the explanations they received in Study 1 and they rated their knowledge lower after hearing an incomplete explanation than a complete one, their average knowledge ratings following the incomplete explanations were still near the midpoint of the scale. Perhaps children felt that the question-and-answer exchanges provided some new information about the animal behavior, even if the answers had gaps, and thus they did not experience a feeling of information deprivation that would have driven them to selectively engage in further learning behaviors. Study 2 was designed to examine the role of information deprivation more closely by emphasizing the missing piece of information in each
vignette. Additionally, rather than rating how much they knew after hearing each explanation, children were prompted to rate how much information they were missing. The explanations were also modified and simplified to further highlight the missing step in the incomplete explanation.

Study 2 also probed whether restricting exploration influences children’s learning behaviors by limiting the number of cards children could take home in the card choice task. Prior research has shown that when children are limited in how much information they can request, they prioritize obtaining information that can fill gaps (Jirout & Klahr, 2012; Mills et al., 2019). Because they could choose to take home all of the animal cards in Study 1, children’s choices may have been driven by general interest in or familiarity with the animals rather than a specific desire to acquire the information that was missing in the explanations. When the number of cards they can take home, and hence their potential for acquiring additional information about the animals, is restricted, children may be more selective and prioritize taking cards that will fill the gaps in their understanding.

Because Study 2 was designed to focus on how feelings of information deprivation and restrictions on information acquisition influenced children’s learning behaviors, it only included measures of biological knowledge and verbal intelligence as potential predictors of individual differences.

3.1. Methods

3.1.1. Participants

Participants included 48 7- to 8-year-old children (24 males and 24 females; M_age = 8.15, range = 7.07–8.97) and 46 9- to 10-year-olds children (26 males and 20 females; M_age = 10.02, range = 9.04–10.99). Children were recruited from the same areas and following the same procedures as in Study 1. The sample’s demographic profile was similar to Study 1 (see supplemental materials for detailed information). No child had participated in the previous study.

3.1.2. Materials and procedure

Explanation Evaluation and Information Seeking Measures. Introduction and Practice Items. Children were told that the experimenter’s friend “Jane” was making a new TV show about animals. The experimenter explained that Jane was getting ready for the show and practicing her answers to questions, and that the participant’s job was to help Jane figure out if her answers were complete or missing information.

Children were then introduced to the missing information scale (see Fig. 2) as a means of indicating how much information was missing from Jane’s answers. The experimenter pointed out that the left-most square had most of the pieces and was missing only 2 pieces, and it meant that the explanation was complete and there was not much information missing. She then pointed out that the right-most square was missing most of the pieces and had only 2 pieces, and that it meant that a lot of information was missing from the explanation. The experimenter explained that children could choose any of the 5 pictures based how much information they thought was there and how much was missing.

Children then completed two practice items involving unfamiliar objects (i.e., a zoetrope and a phonograph) for which they heard a question followed by either a complete explanation of how the object works, or an incomplete explanation (e.g., “The phonograph has a needle. I don’t know how the needle helps it record sounds. But eventually the phonograph is able to record sounds.”) Children rated how much information was missing and received corrective feedback for both examples.

Explanation Presentation. Children viewed the same drawings corresponding to the animal behavior as in Study 1 and the same two stick figures appeared on each side of the screen. However, in Study 2, the figure on the left asked a question and the figure on the right (“Jane”) provided a single complete or incomplete answer. For complete items, “Jane” provided a four-step explanation that included the connecting terms “next” and “after that” to emphasize the causal sequence, e.g., “The badgers find underground tunnels with squirrels in them. Next, they get some soil from the area near the tunnels. The badgers trap the squirrels by blocking all of the tunnel entrances with soil except for one. After that, the badgers can catch the squirrels and eat them.” For incomplete items, the third sentence of the explanation was replaced with a statement of ignorance and connected to the fourth sentence with “but,” e.g., “I’m not sure how getting soil helps the badgers. But, after that, the badgers can catch the squirrels and eat them.”

Following each question-and-answer sequence, children provided a missing information rating and an interest rating. (There was no attention check question in Study 2.) After each pair of incomplete and complete items, children completed the book choice task.

Missing Information Rating. After hearing each explanation, children were asked “How much information is missing from Jane’s answer?” and provided a response using the 5-point puzzle piece scale.

Interest Rating. Identical to Study 1.

Book Choice. Identical to Study 1.

Fig. 2. Missing Information Scale Used in Studies 2 and 3.
Card Choice. The card choice task followed the same procedure as Study 1, except that children were told they could choose up to 5 cards to take home.

Individual Differences Measures. Study 2 included the biological knowledge measure from Study 1. For convenience and to reduce the overall session time, the KBIT2 was replaced by the Picture Vocabulary Test (PVT), which was administered via NIH toolbox software. The working memory and inhibition measures from Study 1 were omitted.

3.2. Results

3.2.1. Explanation evaluation

Preliminary analyses showed no effect of gender or item order so these variables were excluded from further analysis.

Missing Information Rating. A repeated measures 2 (Age Group: 7–8 or 9–10) X 2 (Item Type: complete or incomplete) ANOVA for average missing information ratings revealed a main effect of Item Type, $F(1, 92) = 193.847, p < .001$, partial $\eta^2 = 0.678$. Children rated incomplete items as having more information missing ($M = 3.06, SD = 0.92$) than complete items ($M = 1.67, SD = 0.62$). (See Table S5 for means and SDs by age group.) There were no other significant main effects nor interactions, $F$s $< 1.372, ps > 0.244$. Mean ratings for the incomplete items did not significantly differ from the midpoint of the scale, $t(93) = 0.584, p = .560$, but ratings for the complete items were significantly below the midpoint, $t(93) = 20.82, p < .001$.

3.2.2. Interest and learning behavior measures

Interest Ratings. A repeated measures 2 (Age group: 7–8 or 9–10) X 2 (Item type: complete or incomplete) ANOVA for interest ratings revealed no significant main effects nor significant interactions, all $F$s $< 2.963, ps > 0.089$. Children’s interest ratings for both the incomplete ($M = 3.75, SD = 0.80$) and complete items ($M = 3.78, SD = 0.80$) were significantly higher than the midpoint of the scale, $t$s $> 9.068, ps < 0.001$. (See Table S5 for means and SDs by age group.)

Learning Behaviors: Book Choice. Children chose to hear books corresponding to the incomplete items in 55% of trials (range = 0 to 100%), a rate that is significantly higher than chance, $t(90) = 3.067, p = .003$. There was no significant difference between age groups in rates of choosing the incomplete item books, $t(89) = 0.493, p = .695$ (see Table S5 for means and SDs).

Learning behaviors: Card choice. All children took home at least two cards with the majority (75%) taking home the maximum 5 cards. Children took cards corresponding to the incomplete items ($M = 2.29, SD = 1.08$) and complete items ($M = 2.26, SD = 0.99$) at similar rates. A 2 (Age group) X 2 (Card type: Complete or incomplete item) ANOVA showed a significant main effect of Age group, $F(1, 92) = 4.627, p = .034$, partial $\eta^2 = 0.048$, where younger children took home more cards than older children. There was no significant effect of Card type nor a significant interaction, all $F$s $< 0.89$, $ps > 0.493$. (See Table S5 for means and SDs).

3.2.3. Predictors of individual differences in knowledge, interest, and learning behaviors

Correlations between exact age, missing information ratings, interest ratings, and book and card choice are reported in Table 2.

Missing Information Ratings. Mean missing information ratings for incomplete items were positively correlated with biological knowledge scores, $r(94) = 0.289, p = .005$, and this relation remained significant after controlling for age (which also positively correlated with biological knowledge scores; see Table 2), $r(91) = 0.282, p = .006$. Thus, children with more biological knowledge appeared to be more sensitive to the amount of information missing from the incomplete items than children with less biological knowledge. Because there were no significant correlations between missing information ratings for complete items and biological knowledge scores, nor between missing information ratings for either type of item and PVT scores, $r$s $< 0.174, ps > 0.094$ (see Table 2), regression analyses were not conducted.

Interest Ratings. Interest ratings for the incomplete and complete items were not significantly correlated with missing information ratings for either type of item, all $r$s $< 0.18$, all $ps > 0.089$, suggesting that children’s self-reported interest in learning more about each

|                | M     | SD    | 2.    | 3.    | 4.    | 5.    | 6.    | 7.    | 8.    | 9.    | 10.   |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1. Exact age   | 9.06  | 1.11  | 0.07  | 0.18  | 0.18  | 0.29* | 0.06  | 0.05  | -0.05 | 0.35** | 0.01  |
| 2. Missing info: incomplete | 3.06  | 0.92  | 0.25* | -0.12 | -0.18 | 0.18  | 0.10  | -0.12 | 0.29** | 0.04  | (0.28*) |
| 3. Missing info: complete | 1.67  | 0.62  | -0.08 | -0.10 | 0.02  | 0.16  | -0.06 | -0.18 | (0.12) | -0.17 | 0.17  |
| 4. Interest: incomplete | 3.75  | 0.80  | 0.68*** | 0.17  | 0.31** | -0.16 | -0.23* | (-0.18) | -0.37*** | -0.37*** | -0.37*** |
| 5. Interest: complete | 3.78  | 0.80  | -0.20 | -0.03 | 0.14  | -0.21* | (-0.14) | -0.30* | -0.08 | -0.08 | 0.14  |
| 6. Book choice (proportion) | 0.55  | 0.25  | 0.46** | -0.45** | -0.02 | (0.04) | -0.08 | -0.08 | 0.07  | (0.10) | -0.06 |
| 7. Incomplete item cards taken | 2.29  | 1.08  | -0.65*** | 0.07  | (0.10) | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 | -0.06 |
| 8. Complete item cards taken | 2.26  | 0.99  | -0.09 | (0.08) | 0.07  | -0.09 | (0.08) | 0.07  | -0.09 | (0.08) | 0.07  |
| 9. Biological knowledge | 9.14  | 2.63  | -0.21 | (-0.14) | 0.51*** | -0.09 | (0.08) | 0.07  | -0.09 | (0.08) | 0.07  |
| 10. PVT score   | 107.81| 15.12 |       |       |       |       |       |       |       |       |       |

Note. Correlations controlling for exact age are reported in parentheses for biological knowledge measure (N = 94). Bold font indicates values that remained significant after the Benjamini-Hochberg correction ($q = 0.05$).

* = $p < .05$, ** = $p < .01$, *** = $p < .001$. 

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The card choice task followed the same procedure as Study 1, except that children were told they could choose up to 5 cards to take home.

Individual Differences Measures. Study 2 included the biological knowledge measure from Study 1. For convenience and to reduce the overall session time, the KBIT2 was replaced by the Picture Vocabulary Test (PVT), which was administered via NIH toolbox software. The working memory and inhibition measures from Study 1 were omitted.
item was not related to how much information they judged to be missing from the explanation. Interest ratings for both types of items were also not significantly correlated with biological knowledge (after controlling for age) or PVT scores.

**Book Choice.** There were no significant correlations between missing information ratings or interest ratings and book choice, nor were there any significant correlations between biological knowledge scores (controlling for age) or PVT scores and book choice (see Table 2).

As in Study 1, multilevel modeling examined whether the difference between children’s missing information and interest ratings for each animal item in a pair influenced their corresponding book choice. The first generalized linear multilevel model included participants and the difference between missing information ratings for incomplete and complete items as random effects. The reference category was set such that the results indicate how increases in the child-centered difference score relate to selection of the incomplete item book. The results suggested that there was no significant relation between the difference in child-centered missing information ratings for individual items in each pair and children’s subsequent book choice, $B = 0.075, SE = 0.065, OR = 1.078, 95\% CI = [0.949, 1.225], p = .247$.

Repeating the same procedure with the difference in child-centered interest ratings between the incomplete and complete items, such that positive differences indicate greater interest in the incomplete items, suggested a significant relation between interest in each item and children’s corresponding book choice, $B = 1.150, SE = 0.1348, OR = 3.158, 95\% CI = [2.415, 4.129], p < .001$. For every 1 point increase in the difference between interest ratings for the incomplete and complete items (corresponding to relatively higher interest in the incomplete item than the complete item), children were 216% more likely to choose the book corresponding to the incomplete item.

**Card Choice.** There were no significant correlations between missing item ratings, interest ratings for complete items, or biological knowledge scores (controlling for age) and the number of complete or incomplete item cards children selected (see Table 2). That said, controlling for age, interest ratings for incomplete items positively correlated with the number of incomplete item cards taken, $r(94) = 0.313, p = .002$. This relation suggests that children’s card choices were driven more strongly by their interest than the amount of information they deemed to be missing from the explanations they received. Notably, the number of incomplete item cards taken in this restricted version of the card task was strongly correlated with the proportion of incomplete item books chosen, $r(94) = 0.460, p < .001$, suggesting that children’s choices were consistent across both learning behavior measures.

Multilevel modeling was used to examine the relation between each child’s missing information and interest ratings for each item and whether they chose the card corresponding to that item. Child-centered missing information and interest ratings were generated following the procedure in Study 1. The results showed no relation between child-centered missing information ratings and card choice, $B = -0.128, SE = 0.0769, OR = 0.880, 95\% CI = [0.756, 1.023], p = .096$, and a significant positive relation between child-centered interest ratings and card choice, $B = 0.873, SE = 0.1139, OR = 2.394, 95\% CI = [1.915, 2.994], p < .001$. For every one-unit increase in interest rating for each animal, children were 140% more likely to take home the corresponding card. Thus, when the number of cards that could be taken was restricted, children’s card choices were still more closely linked to their self-reported interest in learning more about the animal rather than to how much information they judged to be missing from the explanation of the animal’s behavior.

### 3.3. Discussion

Children in Study 2 heard causal explanations for unfamiliar animal behaviors that completely described the causal sequence or were missing a key step, and then they indicated how much information was missing from each explanation and how interested they were in learning more about the animal behavior. Across both age groups, children indicated that incomplete explanations were missing more information than complete ones. However, contrary to our expectations, focusing on how much information they were missing rather than on how much they knew (as in Study 1) did not increase children’s interest in learning more about the topics of the incomplete items relative to the topics of the complete items. Furthermore, the amount of information that children indicated was missing from each type of explanation did not predict their learning behaviors in the book choice and card choice tasks. Instead, similar to Study 1, children’s learning behaviors were related to their interest in each topic, which was independent of their missing information ratings.

As in Study 1, there was a positive relation between children’s biological knowledge and their sensitivity to the amount of information missing in the incomplete and complete explanations, suggesting that domain-specific knowledge plays a role in explanation evaluation. Unlike Study 1, though, there was no relation between missing information ratings and verbal intelligence scores. Given that the means and distributions of verbal intelligence scores were similar across participants in the two studies, the absence of a relation between verbal intelligence and explanation evaluation and interest ratings in Study 2 may reflect a difference in the nature of the measures. The KBIT-2 used in Study 1 is designed to tap into children’s broader crystallized knowledge (e.g., it includes questions about the location of major landmarks and the functions of familiar tools), whereas the PVT used in Study 2 measures receptive vocabulary only. In addition, children’s actual learning behaviors did not reflect their biological knowledge or verbal skills: children with higher biological knowledge and PVT scores were as likely to choose the incomplete items in the book and card choice tasks as children with lower scores. Thus, as in Study 1, children’s learning behaviors seemed to be largely independent of their background knowledge.

Study 2 also replicated Study 1 in that there was a global effect of the type of explanation heard on children’s book choices, but not on their card choices. Children chose books that corresponded to the incomplete explanations at rates higher than chance, but, even though the number of cards they could take was limited, children’s card choices did not reflect the type of explanation they had heard about each animal. Although the card choice results are consistent across Studies 1 and 2, they do not align with Mills, Danovitch,
will receive the missing information quickly influences children. Card choices might have been driven by other factors, such as interest in the animals. Study 3 explores the idea that knowing that they
possess the missing information in the incomplete explanation as the basis for their choice.

In order to further explore the basis for children’s learning behaviors, Study 3 also included an open-ended opportunity for children to justify their book choice. We were particularly interested in whether children who chose the incomplete item books would cite the missing information in the incomplete explanation as the basis for their choice.

Due to time constraints involved with allowing children to view their chosen books, individual difference measures were excluded from Study 3.

4. Study 3

The results of Studies 1 and 2 suggest that children’s book choices, but not their card choices, were biased towards learning information that was missing from the incomplete explanations, even though they were not directly related to children’s ratings of their own knowledge or how much information was missing. The discrepancy between children’s decisions in each learning behavior measure might be explained by differences in the amount of time that passed between being deprived of information and being able to choose a book or card (i.e., hearing and having the opportunity to acquire it). Children’s feeling of deprivation and urge to fill a gap might be strongest as soon as they realize they are missing information (i.e., immediately after the incomplete explanation) and weaken as time passes and they engage in other tasks (see Dan et al., 2020 for a similar proposal about adults). Study 3 examines this possibility by examining children’s learning behaviors when they have the option to obtain missing information immediately after hearing a pair of incomplete and complete explanations. We predicted that knowing that they would receive the information immediately would increase children’s preferences for the incomplete item books relative to their preferences in prior studies.

In order to further explore the basis for children’s learning behaviors, Study 3 also included an open-ended opportunity for children to justify their book choice. We were particularly interested in whether children who chose the incomplete item books would cite the missing information in the incomplete explanation as the basis for their choice.

Due to time constraints involved with allowing children to view their chosen books, individual difference measures were excluded from Study 3.

4.1. Methods

4.1.1. Participants

Participants included 46 7- to 8-year-old children (22 males and 24 females; M_age = 7.93, range = 7.01–8.99) and 44 9- to 10-year-olds children (23 males and 21 females; M_age = 10.09, range = 9.04–10.99). Children were recruited from the same areas and following the same procedures as the previous studies except that families did not receive financial compensation. Racial and ethnic representation was similar to the previous studies (see supplementary materials). No child had participated in either of the previous studies. Children were interviewed by a female experimenter in a lab setting or in a quiet space at their school in a session lasting 20 min or less.

4.1.2. Materials and procedure

Explanation Evaluation and Information Seeking Measures. The introduction and practice items, complete and incomplete explanations, missing information ratings, and interest ratings were presented exactly as in Study 2.

Book Choice. The book choice task was slightly modified to inform participants that they would be hearing the book immediately and that the book would be informative. Specifically, the experimenter said: “Now you are going to get a chance to hear a book about one of these animals. The book will teach you more about them. Would you rather hear a book about [animal 1 behavior] or [animal 2 behavior]?” Immediately following their choice, children viewed the corresponding e-book, with the exception of the last book choice trial, where children were prompted to justify their choice before viewing the e-book. The e-books provided illustrated, step-by-step explanations of each animal behavior (see supplemental materials for details about e-book design).

Book Choice Justification. During the last book choice trial, before playing the e-book, the experimenter prompted the child to “tell me why you chose that book to hear.” Children’s answers were recorded and then the child’s chosen e-book was played.

Book Choice Justification Coding. Children’s responses to the book choice question were transcribed and coded by two coders blind to the child’s condition (i.e., which type of explanation the child had heard for each animal). The coding scheme classified children’s justifications for their book choices based on five non-exclusive components: 1) justifications focused on a feeling of deprivation, including missing information or a desire to fill gaps in their knowledge (e.g., “Because for manta rays she told details, but for crows she didn’t tell too many details”), 2) justifications focused on learning (e.g., “[I] wanna learn more about sting rays”) or referring to existing knowledge (e.g., “Because I know more about sting rays than crows”), 3) justifications focused on preferences or liking the topic (e.g., “because I like crows”), 4) justifications citing curiosity (e.g., “Because I wonder how the fish get it off”), and 5) justifications citing interest (e.g., “I thought it was interesting”). Justifications coded as deprivation or learning were also further coded for specificity based on whether the statement referred to the animal in general (e.g., “Because I know more about sting rays than crows”), or to the specific animal behavior described in the explanation (e.g., “Because I didn’t hear much about crows and how they actually open it”). See Appendix B for complete coding scheme.
4.2. Results

Preliminary analyses showed no effects of order or gender. These variables were excluded from further analyses.

Explanation Evaluation. A repeated measures 2 (Age Group: 7–8 or 9–10) X 2 (Item Type: complete or incomplete) ANOVA for average missing information ratings revealed a main effect of Item Type, F(1, 88) = 76.533, p < .001, partial η² = 0.465, and Age Group, F(1, 88) = 7.527, p = .007, partial η² = 0.079. Children rated incomplete items as having more information missing (M = 2.90, SD = 0.90) than complete items (M = 1.91, SD = 0.82), and younger children (M = 2.59, SD = 0.68) gave higher missing information ratings for both item types than older children (M = 2.22, SD = 0.61). There was no significant interaction between Item Type and Age Group, F(1, 88) = 1.977, p = .163, partial η² = 0.022. Mean ratings for the incomplete items did not significantly differ from those for the complete items, t(89) = 1.011, p = .315, but ratings for the complete items were significantly below the midpoint, t(89) = 12.538, p < .001.

Interest and Learning Behavior Measures. Interest Rating. A repeated measures 2 (Age group: 7–8 or 9–10) X 2 (Item Type: complete or incomplete) ANOVA for interest ratings revealed no significant main effects nor significant interactions, all Fs < 2.785, ps > 0.099. Children’s interest ratings for both the incomplete (M = 3.83, SD = 0.75) and complete items (M = 3.79, SD = 0.69) were significantly higher than the midpoint of the scale, t.s > 10.445, ps < 0.001.

Learning Behaviors: Book Choice. Overall, children chose the incomplete items books 58% of the time (range = 0 to 100%), a rate significantly higher than chance, t(89) = 3.053, p = .003. There was no significant difference between age groups in rates of choosing the incomplete item books, t(88) = 1.652, p = .102.

Predictors of Individual Differences in Missing Information Ratings, Interest Ratings, and Book Choice. Correlations between exact age, missing information ratings, interest ratings, and book choice are reported in Table 3.

Missing Information Ratings. Children’s mean missing information ratings for complete items negatively correlated with age, r (86) = -0.429, p < .001, such that older children gave higher missing information ratings for complete items (see Table 3). There was, however, no significant correlation between missing information ratings for incomplete items and age, r(86) = -0.064, p = .548.

Interest Ratings. Controlling for age, children’s interest ratings for incomplete items were significantly negatively correlated with missing information ratings for incomplete items, r(86) = -0.289, p = .006, such that children who felt they knew more information (i.e., were missing less information) expressed more interest in learning about the incomplete items. There was no significant correlation between missing information ratings for complete items and interest ratings for the complete items, r(86) = 0.117, p = .276.

Book Choice. Controlling for age, there were no significant correlations between book choice and missing information ratings, rs < 0.111, ps > 0.301, but there was a significant positive correlation between choice of the incomplete item books and interest ratings for incomplete items, r(86) = 0.277, p = .009, and a negative correlation with interest ratings for complete items, r(86) = -0.326, p = .002. Thus, children’s choice of incomplete books aligned with their interest ratings for both types of items.1

Following the multilevel modeling procedure from Study 2, we found no significant relation between the difference in children-centered missing information ratings for individual items in each pair and children’s subsequent book choice, B = 0.131, SE = 0.085, OR = 1.140, 95% CI = [0.965, 1.348], p = .124, but there was a significant relation between interest in each item and children’s corresponding book choice, B = 1.166, SE = 0.138, OR = 3.208, 95% CI = [2.440, 4.219], p < .001. For every 1 point increase in the difference between interest ratings for the incomplete and complete items (corresponding to relatively higher interest in the incomplete item than the complete item), children were 221% more likely to choose the book corresponding to the incomplete item.

Together with the correlations between overall interest ratings and book choice reported above, these findings suggest that children’s interest ratings were directly linked to their book choice for each pair of items.

Justifications. Two trained raters blind to the child’s book choice coded 50% of the sample together with 96.94 percent agreement (Cohen’s Kappa = 0.892) with kappa values for individual codes ranging from 0.727 to 1.00. Disagreements were resolved through discussion. Each coder then coded 25% of the sample on their own. One 7-year-old was not asked the justification question because his session unexpectedly ended early, and two 7-year-olds said “I don’t know” or did not respond to the question. Nine additional children provided responses that were off-topic or ambiguous (e.g., “Because insects like other foods and other things,” “Because it’s a great book to read”). Of the 78 remaining responses that were subsequently coded into one of the primary categories, 62 were coded into one category only and 16 were coded into two categories.

Chi-square analyses (with Yates Continuity Corrections) were used to analyze differences in the types of justifications children provided for selecting the incomplete item book (n = 55) or the complete item book (n = 34; see Table 4). Justifications alluding to deprivation were only provided by children who chose the incomplete item book, χ² (1, n = 89) = 15.980, p < .001, phi = 0.451. In fact, 40% of children (22 of 55) who chose the incomplete item book cited deprivation in their justification. In all but one case, children described experiencing information deprivation in general terms, with only one child citing a lack of information about the specific animal behavior. Children who cited deprivation were significantly older (M_deprivation = 9.62, SD = 1.00) than children who chose the incomplete book but who did not cite deprivation (M_no-deprivation = 8.71, SD = 1.19), t(53) = 2.198, p = .005, and they had higher biological knowledge scores, t(53) = 2.921, p = .005. They also gave higher missing information ratings for the incomplete items, t(53) = 2.584, p = .013, and lower missing information ratings for the complete items, t(45.26) = 3.605, p = .001 (equal variances not assumed due to Levene’s test, F = 11.826, p = .001), than the 33 children who did not cite deprivation, but their interest ratings did not significantly differ from children who chose the complete item.

1 One might argue that missing information ratings, interest ratings, and book choice for the first pair of items should be omitted from analyses as children did not yet have the experience of immediately hearing their selected book. However, if the analyses are repeated without the first set of items, the pattern of results remains the same.
differ. Thus, citing deprivation appears to be associated with increased sensitivity to the presence or absence of information in the explanations.

There were no significant differences between groups in the proportion of justifications citing a desire to learn, χ² (1, n = 89) = 0.002, p = .962, phi = 0.029, or liking the chosen animal, χ² (1, n = 89) = 0.017, p = .898, phi = 0.156. Among the 33 justifications citing a desire to learn more about the animal, an equal number described wanting to learn about the animal in general (16 justifications) or about the specific animal behavior (16 justifications), with one justification citing both.

Children who chose the complete item book were significantly more likely to justify their choice based on interest in the animal than children who chose the incomplete item book, χ² (1, n = 89) = 6.214, p = .013, phi = -0.294. Because they were provided so infrequently, justifications coded as involving curiosity or those that were ambiguous did not meet assumptions for chi-square analyses. That said, it is notable that over 20% (7/34) of the justifications that children who chose the complete item book provided were coded as ambiguous, whereas only 4% of the justifications (2/55) that children who chose the incomplete item book provided were coded as ambiguous (p = .014, Fisher’s exact test, one-tailed).

4.3. Discussion

The results of Study 3 largely replicate the results of the prior studies. Children in both age groups rated incomplete explanations as missing more information than complete explanations, yet they expressed similar levels of interest in learning more about the topics of each type of explanation. Children in Study 3 also selected the incomplete item books more often than the complete item books in the book choice task, and they did so at similar rates as the prior studies. Thus, immediately receiving the information after selecting the book did not provoke a stronger preference for the incomplete item book than when children expected to receive the information later. Study 3 also replicated the finding that interest ratings were related to the proportion of incomplete item books chosen, and that the difference in interest ratings between the incomplete and complete items in each pair was predictive of specific book choices. Together, these results reinforce the conclusion that children’s learning behaviors were primarily motivated by interest in the topic, rather than by how much information they believed they had received about it.

Although the amount of information missing from an explanation did not seem to directly drive children’s book choices, children’s justifications for their choices suggest that deprivation did play a role in some children’s decisions. A large minority of children who chose the incomplete item book cited the information gap in their justifications. In contrast, children who chose the complete item book never mentioned the information gap, and they were more likely to give ambiguous explanations than children who chose the incomplete item book, perhaps reflecting that their choice was not driven by a particular motivation to learn about that topic. These findings suggest that, even though children’s book choices were not related to their missing information ratings, the act of judging how much information was absent from each explanation may have still provoked a sense of deprivation which subsequently affected children’s book choices.

### Table 3
Correlation Matrix for all Primary Study Variables in Study 3.

|   | M  | SD | 2.  | 3. ** | 4. ** | 5. ** | 6. ** |
|---|----|----|-----|-------|-------|-------|-------|
| 1. Exact age | 8.98 | 1.24 | -0.06 | -0.43 ** | 0.83 | -0.20 | 0.15 |
| 2. Missing info: incomplete | 2.90 | 0.90 | – | 0.21 (0.20) | -0.28 ** (-0.29 **) | -0.07 (-0.09) | -0.01 (0) |
| 3. Missing info: complete | 1.91 | 0.82 | – | 0.01 (0.07) | 0.19 (0.12) | 0.17 (-0.11) | – |
| 4. Interest: incomplete | 3.82 | 0.75 | – | 0.39 ** (0.46 **) | 0.31 ** (0.28 **) | – | – |
| 5. Interest: complete | 3.79 | 0.69 | – | – | – | -0.35 ** (-0.33 **) | – |
| 6. Book choice (proportion) | 0.58 | 0.26 | – | – | – | – | – |

Note. Correlations controlling for exact age are reported in parentheses (N = 94). All significant p-values remained significant after the Benjamini-Hochberg correction (q = 0.05).

* = p < .05, ** = p < .01, *** = p < .001.

### Table 4
Frequency of Justification Codes for Incomplete and Complete Book Justifications in Study 3.

| Justification code | Incomplete (n = 55) | Complete (n = 34) |
|-------------------|---------------------|------------------|
| Deprivation       | 22                  | 0                |
| Learning          | 21                  | 12               |
| Liking            | 11                  | 8                |
| Interest          | 5                   | 11               |
| Curiosity         | 3                   | 1                |
| Ambiguous         | 2                   | 7                |
| No response       | 2                   | 0                |
5. General discussion

In three studies, children ages 7–10 heard causal explanations of animal behaviors in the context of a question-and-answer exchange between two individuals. When the causal explanations were missing a key intermediate step (i.e., were incomplete), children consistently recognized them as providing less knowledge or missing more information than complete explanations. Rather than comparing two explanations of different quality, as in most prior work (e.g., Baum et al., 2008; Corriveau & Kurkul, 2014), children evaluated single explanations. These explanations were more verbally complex than in previous studies (e.g., Corriveau & Kurkul, 2014; Mills et al., 2017) and although the missing step was clearly marked during the question-and-answer exchange (i.e., the speaker said “I don’t know what happens next”), the incomplete explanations still provided some relevant new information. Thus, the current findings support and extend previous work on weak explanations (particularly Mills et al., 2017) by demonstrating that children as young as age 7 recognize that less knowledge is gained from incomplete explanations than complete explanations.

5.1. Explanation evaluation

Age was not related to knowledge or missing information ratings, suggesting that children’s ability to recognize clearly marked gaps in explanations is relatively stable across the mid-elementary school years. However, cognitive factors, including verbal intelligence, biological knowledge, and working memory, were related to children’s knowledge ratings after hearing incomplete explanations. Verbal intelligence was the strongest predictor of knowledge ratings, and it was inversely related to knowledge ratings, suggesting that children who have more domain-general verbal knowledge believe they know less after hearing an incomplete explanation than children with less verbal knowledge. This finding aligns with prior work demonstrating that children who score higher on intelligence measures are more conservative when rating their own knowledge than children with lower scores (Danovitch et al., 2019), and that, like adults, children who are less knowledgeable might be less aware of what they do not know (i.e., the Dunning–Kruger effect; Dunning, 2011). That said, the absence of a correlation between missing information ratings and PVT scores in Study 2 suggests that there is some nuance to this connection. One possibility is that broader crystallized knowledge (as measured by the KBIT-2) contributes to children’s explanation evaluation more than semantic knowledge (as measured by the PVT). Alternatively, when it is relatively easy to evaluate an explanation and the task is less verbally demanding (such as in the simplified single question and answer presentation in Study 2), verbal skills may be less crucial. Further research is necessary to better understand how domain-general knowledge and verbal skills contribute to explanation evaluation in different contexts.

The results of Studies 1 and 2 also provide evidence for a relation between domain-specific knowledge and explanation evaluation. More specifically, children with higher biological knowledge scores rated themselves as knowing less or as missing more information after hearing incomplete items than children with lower biological knowledge scores. Children’s biological knowledge may correspond with their experience encountering and interpreting biological explanations, and children who are more aware of other causal patterns present in biological systems may be more sensitive to the missing information in the incomplete explanations. This possibility is supported by the fact that, for both verbal intelligence and biological knowledge, significant correlations with knowledge or missing information ratings were only present for the incomplete explanations. Thus, children with more background knowledge were not simply more critical of all explanations than children with less background knowledge, but rather they may have been more sensitive to the unique weaknesses of the incomplete explanations. Together, these findings suggest that both domain-general and domain-specific knowledge may scaffold children’s learning by supporting their ability to recognize gaps in explanations.

5.2. Self-reported interest in learning

Like the knowledge ratings and missing information ratings, children’s self-reported interest in learning additional information about the topics of the explanations was consistent across age groups. Children expressed high levels of interest in learning about the animals across all three studies, and they maintained this high level of interest for both complete and incomplete explanations. In some ways, their interest was not surprising: we intentionally chose to focus on questions about animals because children show interest in this topic from a young age (Inagaki & Hatano, 2006; LoBue et al., 2013). That said, children’s already high level of interest may have made them less susceptible to experimental manipulations intended to induce additional interest, such as receiving incomplete answers.

Although there was no consistent relation between the type of explanation received and children’s self-reported interest in learning, there was some evidence for an indirect link between explanation evaluation and interest. In two of our studies, feeling knowledgeable after hearing the incomplete items was linked to stronger interest in the other type of item (Study 1) or weaker interest in learning more about the incomplete items (Study 3). There were also negative correlations between children’s verbal and biological knowledge scores and their interest ratings in Studies 1 and 2. In other words, children with more background knowledge reported less interest in learning more about the animals than children with less background knowledge. Perhaps generating ratings was more difficult for less knowledgeable children, or they had less insight into their feeling of interest, leading them to give high interest ratings regardless of the item. It is also possible that children with more background knowledge already knew more about the animals at hand or felt like they could fill in the gaps themselves, leading them to report less interest in learning. This possibility is supported by recent work suggesting that young children who have some basic knowledge about a topic, but who are still developing their understanding of that topic, show more interest in obtaining relevant information than children who are more knowledgeable (Wang et al., 2021). Future research might further explore how existing knowledge contributes to differences in children’s self-reported interest in gaining information to fill an explanatory gap.
5.3. Learning behaviors

Although asking children to report on their level of interest is informative, generating nuanced interest ratings may have been challenging for children, particularly when their interest level was already high. Thus, children’s actual engagement in learning behaviors may provide a clearer picture of children’s interest in learning than self-report. In the current studies, learning behaviors were measured in two ways: book choice and card choice. The card choice measure – which children completed after the other experimental tasks, including the book choice task – allowed children to either take home as many animal fact cards as they wanted (Study 1) or up to a maximum number of cards (Study 2). Children selected cards corresponding to incomplete items or complete items at similar rates. That said, had the cards been presented as a forced-choice between two cards immediately following the explanation evaluations, children may have shown the same preferences as in the book choice task. As discussed earlier, because book choice always preceded card choice, selecting a book may have satisfied children’s desire for additional information after hearing the explanations, so that their subsequent card choices were driven by other considerations. Indeed, multilevel modeling revealed that specific book and card choices were more closely linked to interest ratings for those items than to knowledge or missing information ratings, suggesting that children’s selections were primarily driven by interest rather than a sense of missing a piece of information. The link between the cards and the specific gaps discussed in the study may have also seemed tenuous, as the cards featured a color photo and multiple facts about the animal, while the explanation presentation included a black and white drawing and focused on a single fact. Finally, it is possible that some children had forgotten which explanations were complete or incomplete by the end of the study, and thus based their card choices on other factors.

In contrast, across all three studies, children selected books that corresponded to the topics of the incomplete explanations at rates above chance. In other words, when children had to choose between a book that filled a gap and a book that did not, they tended to choose the book that filled a gap. That said, there is some tension here: although children showed a consistent preference across all three studies, the proportion of incomplete books chosen was not affected by whether they were focused on evaluating the explanations on other factors, but other children (including the ones who cited deprivation) may have perceived the missing information as holding enough new information that it was not worthwhile for them to seek out the missing information and so they chose books based on other factors.

There may also have been individual differences in how children responded to the incomplete explanations. Hearing incomplete explanations may have piqued some children’s interest in learning more to fill the explanatory gap, while diminishing interest among other children. Similar patterns have been documented among adults, where some adults prefer more detailed mechanistic explanations and others avoid them (Fernbach et al., 2013), and among preschoolers, who vary in the degree to which they seek out and prefer causal information (Alvarez & Booth, 2016; Booth et al., 2020).

Although children chose the incomplete item books at rates above chance, the fact that they selected them only 55–58% of the time suggests that children’s preference for these books was influenced by factors beyond the presence or absence of information gaps. One explanation for this pattern is that some children felt a strong immediate urge to acquire the missing information - and these are the same children who cited deprivation in their explanations - while others only experienced a global sense of increased interest (see Dan et al., 2020 for a similar proposal about adults). If this were the case, interest ratings would have generally been high for all children (as in the current studies), but children would only have selected the incomplete item books in some trials.

Another potential explanation for variability in book choice comes from recent evidence that, for adults, knowledge acquisition is predicted by expectations about the information’s future utility (Liquin & Lombozo, 2020) or value with respect to personal goals (Murayama et al., 2019). If children take similar considerations into account, then their interest ratings and learning behaviors in our studies may have been influenced by individual differences in whether they perceived gaining additional information about the animal behaviors as functionally useful or rewarding. For example, some children might have seen incomplete explanations as providing enough new information that it was not worthwhile for them to seek out the missing information and so they chose books based on other factors, but other children (including the ones who cited deprivation) may have perceived the missing information as holding potential benefits in the future so they prioritized obtaining the missing information when making book choices.

5.4. Limitations

There are several limitations to the current studies. First, the character answering the question openly acknowledged that there was a gap in their explanation with language including “I don’t know,” potentially signaling to the child that there was more to learn. But this is not always the case when adults answer children’s questions (Mills et al., in press), and, had the character not explicitly signaled their ignorance in our studies, children may have been less likely to notice the gap in the explanation and it may have had a weaker influence on their book choices. Moreover, when an explanatory gap is not clearly signaled, children may be less motivated to seek out the missing information. Second, although the children in our sample had diverse racial and ethnic backgrounds, they tended to be from higher socioeconomic status backgrounds, and their families had opted to participate in a university-sponsored research study.
about science. Children from lower socioeconomic status backgrounds may hear fewer causal explanations than children from higher socioeconomic status backgrounds (Tizard & Hughes, 1984) and, thus, they may respond differently to incomplete explanations than children from higher socioeconomic status backgrounds (Kurkul & Corriveau, 2018). Extending the current methods to a more culturally diverse sample would also elucidate the role of sociocultural differences in children’s explanation evaluation and information seeking. There may be sociocultural differences in children’s familiarity with print-based sources, such as the books and cards in our studies, that influenced children’s likelihood of engaging in the learning behaviors that we measured. Perhaps our results would have differed if children had the opportunity to access the additional information in other formats, such as a website or game explored at their own pace (Mills et al., 2019). Likewise, given the generally high level of interest in animals among the children in our studies, future work might explore whether similar patterns of results emerge in other domains, including those that may be of lower interest.

Finally, it is important to keep in mind that although we measured children’s interest in learning more about the animals in our studies and the actions they took to do so, we did not measure their actual learning. Recent evidence suggests that learning is strongly tied to prior knowledge in a domain, and that curiosity or interest play a relatively minor role (Wade & Kidd, 2019). Moreover, curiosity about the question, rather than the answer, may be critical for children’s learning and recall of new information (Fandakova & Gruber, 2021). Future research should explore how hearing a complete or incomplete explanation and choosing to obtain additional information affects children’s understanding and memory for an explanation. It may also be worthwhile to measure children’s interest in a target question prior to hearing the response.

5.5. Conclusions

Taken together, the current findings suggest that receiving incomplete explanations influences children’s interest and learning behaviors in subtle ways that are not a direct function of explanation evaluation. These findings provide some support for the information-gap theory of learning (Loewenstein, 1994), but they also suggest that other factors, such as background knowledge, influence whether children engage in learning behaviors when they experience information deprivation. Understanding these factors has implications for motivating children’s learning in formal and informal contexts, and for explaining individual differences in children’s motivation. For example, receiving a partial answer to a question about a scientific process could have differential effects on children’s science learning. Some children, such as those with less background knowledge or higher interest in the topic, may become more motivated to learn about the topic and fill the information gap, while other children, such as those with more background knowledge, may feel like they have enough prior knowledge to close the gap themselves. Understanding the interactions between the answers that adults provide and individual differences in children’s responses to explanatory gaps can help us better understand how to support children’s learning and exploration when they encounter new information.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank members of the UTD Think Lab and the University of Louisville KID Lab for their assistance with data collection and entry, as well as Robert Ackerman for support with statistical analyses. This work was supported by National Science Foundation Grant DRL-1551862, awarded to Judith Danovitch, and DRL-1551795, awarded to Candice Mills.

Appendix A

Initial questions and complete explanations of animal behaviors used in studies 1, 2, and 3

| Initial question                                                                 | Complete explanation                                                                 |
|--------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Sea otters catch live crabs to eat, but sometimes they wait to eat them. How do   | The sea otters catch a live crab in their paws. Next, they get a piece of seaweed.   |
| some sea otters keep the crabs so that they can eat the live crabs later?         | The sea otters wrap the crab in a piece of seaweed so that the crab can’t move.       |
| Crows eat nuts, but sometimes they find nuts that they cannot open with their     | Then the sea otters keep the live crab to eat later.                                 |
| beaks. How do some crows open nuts that they cannot open with their beaks?       | The crows find nuts that they cannot open with their beak. Next, they fly into the    |
| Frogs drink water, but sometimes the air is dry and there is no water around.    | the sky carrying the nuts. The crows drop the nuts so that the nuts break open         |
| how do some frogs survive when there is not any water for them to drink?         | when they hit the ground. Then the crows can eat the insides of the nuts.            |
| Buffaloes like to eat grass, but sometimes while they are eating, insects land on | The buffaloes are annoyed by insects biting their skin. Next, they rub cedar and      |
| them and bite them. How do some buffaloes keep insects from biting them?         | pine tree trunks with their horns. The buffaloes start to smell like cedar and       |

(continued on next page)
(continued)

| Initial question                                                                 | Complete explanation                                                                 |
|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Manta rays swim in the ocean, but as they swim they get dirt and germs on their skin. How do some manta rays keep their skin clean? | The manta rays get germs and dirt stuck to their skin. Next, they visit a place full of different kinds of fish. Small fish and shrimp eat the dirt and germs off the manta ray’s skin. Then the manta rays are able to keep their skin clean. |
| Badgers like to eat squirrels, but the squirrels hide from them in small tunnels underground. How do some badgers catch squirrels that hide in small tunnels underground? | The badgers find underground tunnels with squirrels in them. Next, they get some soil from the area near the tunnels. The badgers trap the squirrels by blocking all of the tunnel entrances with soil except for one. Then the badgers can catch the squirrels and eat them. |
| Herons like to eat fish, but sometimes the fish are too deep in the water for them to reach. How do some herons catch fish from lakes to eat? | The herons go to a lake that has fish in the water. Next, they grab an insect from the air. The herons drop the insect into the lake so that fish swim to the surface to eat it. Then the herons catch the fish that live deep in the lake. |
| When sea lions move on land, they kick up a lot of sand into the air. How do some sea lions protect their eyes from sand while still being able to see? | The sea lions kick up a lot of sand into the air. Next, they close their eyelids. The sea lions’ eyelids are see-through and stay closed to protect their eyes. Then the sea lions can see while keeping sand out of their eyes. |
| Dolphins eat fish that live in the rocky sand at the bottom of the ocean, but the rocks hurt their noses. How do some dolphins catch fish in rocky sand without getting hurt? | The dolphins search for fish in the rocky sand. Next, they look around and find a sea sponge. The dolphins put the sponge on their noses to protect them while digging in the rocky sand. Then the dolphins catch fish without hurting themselves. |
| Crocodiles spend a lot of time in the water waiting for their prey to come to the water’s edge. How do some crocodiles keep their bodies underwater when they float? | The crocodiles look for prey and try to hide. Next, they find some stones near the shore. The crocodiles eat the stones, and the stones act as weights to keep their bodies underwater. Then the crocodiles are able to stay underwater. |

**Appendix B**

Book choice justification coding scheme (Study 3)

Children’s responses were coded into the following seven categories (with corresponding subcategories for deprivation and learning codes):  

| Code           | Description                                                                                                                                 |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| Curiosity      | Refers to “wonder” or curiosity about the topic (but not interest)                                                                             |
| Deprivation    | Refers to absent or missing information in the prior explanations                                                                             |
| General        | Refers to animal(s) only e.g., “Because there was information missing about X”                                                                |
| deprivation    | Refers to animal behavior from item e.g., “because it didn’t say how the X does Y”                                                             |
| Learning       | Refers to wanting to “learn” more about the topic(s) or references to existing knowledge; could also refer to prior knowledge (e.g., “Because I already know a lot about X”) or lack thereof (e.g., “Because I don’t know much about X”) |
| General learning | Refers to animal(s) only e.g., “Because I want to learn more about X”                                                                          |
| Specific learning | Refers to animal behavior from item e.g., “Because I wanted to learn more about how X does Y”                                              |
| Liking         | Refers to a positive or negative view of topic e.g., “Because I like (or don’t like) X,” “Because X is my favorite animal”                |
| Interest       | Expresses interest in the topic e.g., “Because X are really interesting,” “because that book sounds more interesting”         |
| Ambiguous      | Statement is about the topic but does not indicate a clear reason for choosing topic; includes non-answers and repetition e.g., “Because I wanted to hear it,” “Because I want to see X” |
| No response    | Child said “I don’t know” or provided no response                                                                                           |

**Appendix C. Supplementary data**

Supplementary data to this article can be found online at [https://doi.org/10.1016/j.cogpsych.2021.101421](https://doi.org/10.1016/j.cogpsych.2021.101421).

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