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Are Prompts Provided by Electronic Books as Effective for Teaching Preschoolers a Biological Concept as Those Provided by Adults?

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ABSTRACT

Research Findings: Prior research indicates that shared book reading is an effective method for teaching biological concepts to young children. Adult questioning during reading enhances children's comprehension. We investigated whether adult prompting during the reading of an electronic book enhanced children's understanding of a biological concept. Ninety-one 4-year-olds read about camouflage in 3 conditions. We varied how prompts were provided: (a) read by the book, (b) read by a researcher, or (c) given face to face by the researcher. There was an interaction between children's initial vocabulary level and condition. Children with low vocabulary scores gave fewer camouflage responses than their high-vocabulary peers, and this effect was particularly pronounced in the book-read condition. Children's executive function was also measured and discussed. *Practice or Policy*: Our findings indicate that under some circumstances electronic prompts built into touchscreen books can be as effective at supporting conceptual development as the same prompts provided by a coreading adult. However, children with low vocabulary skills may be particularly supported by adult-led prompting. We suggest that adult prompting be used to motivate children to test and revise their own biological theories. Once children have learned strategies for updating their concepts, electronic prompting may be useful for scaffolding children's transition to using the strategies when reading alone.

Technology, despite some resistance against it, is being increasingly embraced by parents for use with young children. Recent surveys indicate that 80% of U.S. children ages 2–4 have had experience using mobile devices (Rideout, 2013), and 65% of 3- to 4-year-olds in the United Kingdom have access to tablets at home (OfCom, 2014). In addition to home use, technology is also being incorporated into school curricula, as proficiency with technology is considered part of the Common Core State Standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Although technology may be less universal in preschool settings than in elementary settings, one survey of U.S. educators of children ages 0–4 found that 28% had classroom tablet computer access and 83% had classroom desktop or laptop computer access (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013). A wide variety of educational software is available that targets preschool children, but how educational is it? In this research we are particularly interested in the role of interactive touchscreens in children's learning about the biological concept of camouflage.

Because shared reading experiences provide an opportunity for high-quality prompting, they make an excellent platform for teaching biological concepts to young children. Biological

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information often includes information that cannot be seen in everyday life with the naked eye. Books provide pictures and text that can give children a window into other worlds such as the animal kingdom or the inside of the body.

Learning About Biology Through Books

A growing number of studies indicate that young children can learn biological facts and concepts through shared book reading. For example, Walker, Gopnik, and Ganea (2015) found that 3-, 4-, and 5-year-old children can learn and transfer a biological causal relation (a "popple flower" causing the hiccups) encountered in a story context to a real context if the fictional context of the story is similar to the real-world story. Children 5–8 years of age can also learn a conceptually coherent explanation of natural selection from a story picture-book intervention and apply that explanation to a novel population of animals (Kelemen, Emmons, Schillaci, & Ganea, 2014). Ganea, Canfield, Simons-Ghafari, and Chou (2014) also found that 4- and 5-year-olds readily learned facts about three new animals' (cavies, oxpeckers, and handfish) behavior and environment when they were presented in a realistic context.

Exposure to books can also influence how children reason about animals at a more general level. For example, Waxman, Herrmann, Woodring, and Medin (2014) found that 5-year-olds who read an encyclopedia about bears were more likely to later adopt a biological pattern of reasoning about bears than children who read a book from the popular children's storybook series *The Berenstain Bears*. Children who read the more anthropomorphic book instead later reasoned that bears were more like humans. Similarly, Ganea and colleagues (2014) showed that 4- and 5-year-olds attribute more anthropomorphic traits to animals after being exposed to books that use anthropomorphic pictures and language than after being exposed to books that use factual language and realistic pictures of animals. In this study, the children likewise learned more facts about novel animals and their environment when exposed to these realistic books than when exposed to the anthropomorphic books. Finally, Geerdts, Van de Walle, and LoBue (2015) showed that preschoolers who were read anthropomorphized stories about butterflies and frogs used anthropomorphic language when retelling the stories, but children who heard stories with factual language did not. However, unlike in the studies by Ganea and colleagues (2014) and Waxman and colleagues (2014), children in this study did not attribute anthropomorphic qualities to other animals and explained other camouflage scenarios with equivalent language regardless of the type of book they had read. The authors hypothesized that the less extreme anthropomorphic portrayal of the animals in their books (animals had human-like faces and postures but appeared in natural environments) compared to the ones used in other stories (animals in houses wearing clothes and using furniture) may be one reason why they did not see the same generalization of anthropomorphism as the prior studies (Geerdts, 2015).

In other research, Ganea, Ma, and DeLoache (2011) showed that children could learn and transfer broader, generalizable conceptual knowledge from picture books. They found that 4-year-olds could learn to reason about the biological adaptation of camouflage from reading a realistic picture book about animals on various backgrounds. Prior to reading, children's conceptual knowledge did not allow them to generate camouflage-based reasoning about why a bird would choose a particular prey; however, after reading children not only generated camouflage-based explanations for the animals presented in the book (frogs) but also transferred that knowledge to different live animals in tanks (lizards and crabs).

Thus, shared reading experiences appear to be an excellent source for preschoolers to develop generalizable biological concepts. In this study we built on Ganea and colleagues' (2011) study by using electronic books and adding high-quality prompting to drive conceptual development about camouflage. Here we investigated whether asking children to make predictions and give explanations about camouflage, coupled with feedback, is effective in increasing children's use of appropriate camouflage-related reasoning about a predator–prey situation. In addition, we addressed whether electronic questioning is equally as supportive as questioning provided in person by varying the source of the prompts given to children: an electronic text reading itself, an adult reading text, or an adult face to face. Finally, we asked whether children's language skills or executive function moderate their learning.

The Use of High-Quality Prompts to Support Conceptual Change

Children learn best from shared reading experiences when those experiences are paired with adult scaffolding, such as with the popular program dialogic reading (Mol, Bus, de Jong, & Smeets, 2008). Research on children's story comprehension shows that adult questioning during shared reading is linked to increases in knowledge of story content. For example, when teachers prompt children for cognitively challenging talk during reading or question children about content before or after reading, children's knowledge of the content is increased (Dickinson & Smith, 1994; Morrow, 1984).

Questions that promote inferencing, or drawing connections between events in the story, seem to be especially supportive of story comprehension. Prompting children to draw inferences and modeling doing so is something that parents often do when reading with preschoolers (van Kleeck, 2008). Explicitly prompting children to make inferences could support children's understanding by focusing them on the causal chain of events in the story (Kendeou et al., 2005; Makdissi & Boisclair, 2006).

One specific type of prompt involves asking children to make *predictions* about upcoming story events. This type of prompt may act as an important support for building conceptual knowledge. Prediction involves combining existing knowledge with new information from the text to generate ideas about what might occur (Duke & Pearson, 2002). When predictions are made during reading, children who continue through the story are provided with feedback as to whether their predictions played out and have the opportunity to update their understanding. The process of integrating existing beliefs with new observations and instruction is the basis for building conceptual knowledge (Vosniadou & Ioannides, 1998). When children note inconsistencies between what they think will happen and what really happens, it provides motivation for them to update their conceptual knowledge (Carey, 2009). Thus, asking children to make predictions during shared reading, then continuing to see whether the prediction plays out, may provide motivation for children to update their relevant conceptual theories.

Although some children may generate predictions on their own while reading, Vosniadou and Ioannides (1998) noted that many children tend to think of their explanatory frameworks as facts they know rather than ideas that need to be tested. They proposed that instructional interventions for conceptual learning should make students aware of limitations in their current understanding and motivate them to reshape their beliefs. Thus, explicit prompting of children to make and explain their predictions may be needed to motivate children to recognize the inconsistences between their theories and subsequent events.

Explanation may also help encourage children to draw inferences and generalize information they have encountered. When asked to explain a mechanical event they have observed, children often use general rules that take all evidence into account (Walker, Williams, Lombrozo, & Gopnik, 2012) and focus on functional rather than superficial properties (Legare & Lombrozo, 2014; Walker, Lombrozo, Legare, & Gopnik, 2014). If asking for explanations about an event prompts children to think both generally and causally, then asking children to provide an explanation after they make a prediction may motivate them to think more deeply about their conceptual theory, potentially motivating conceptual change.

Mere motivation to update a concept, however, is not necessarily enough—to build better concepts children also need good information about *why* their prediction was incorrect (Carey, 2009). Thus, explicit *feedback* regarding children's prediction could also be an important scaffold that adults can provide.

Vosniadou (2007) argued that even very young children can make predictions and explanations about novel situations based on naïve theories built through their experiences. New experiences in a particular domain can be incorporated as children reshape their existing domain-specific theories. In this study, we gave children the opportunity to test their predictions and explanations in the biological domain using camouflage, which has been shown to be age appropriate and engaging for children ages 3–4 (Brown & Kane, 1988; Ganea et al., 2011).

It is particularly valuable to understand the nature of change in children's biological concepts. Biology is a topic that even very young children spontaneously pay attention to and engage with (Inagaki & Hatano, 2002). Naïve biology is reshaped and constructed through early life experiences, gradually growing to incorporate more advanced concepts, like natural selection. A number of individual concepts are foundational to a coherent understanding of natural selection as a process (Kelemen et al., 2014). Two such concepts are trait variation within a population and differential health and survival. It is on these individual concepts that an understanding of evolution can eventually be built. Acquiring the concept of camouflage necessarily involves understanding trait variation (color) and differential survival (invisibility to predators leads to increased survival chances). Integration of these foundational concepts may support children in later reasoning about evolutionary processes, as some have argued that evolutionary processes are counterintuitive and foundational concepts are important for building accurate evolutionary theories (Evans et al., 2010).

In the current study, we created an electronic book designed to teach 4-year-olds about the biological concept of camouflage. At three points in the book children were prompted to apply their conceptual knowledge, make a prediction about what would happen next, and give an explanation for their prediction. They were then given feedback as to whether their prediction played out the way they expected and an explanation as to why or why not.

The Use of Electronic Prompting

Although adult-led prompting has been widely studied as an educational intervention for a variety of language and comprehension skills, prompts from media sources themselves have not received much attention. Studies have shown that scripted prompts embedded into books are effective at increasing language learning when read by researchers (Ard & Beverly, 2004; Van Kleeck, Woude, & Hammett, 2006). However, to our knowledge, prompts that are read from the page have never been compared to prompts provided by a more naturalistic, face-to-face means. Because young children are highly attuned to pedagogical cues from adults to help them determine when something is instructional and should be learned or transferred (Bonawitz et al., 2011; Butler, Schmidt, Bürgel, & Tomasello, 2015; Sobel & Sommerville, 2009), we hypothesized that more naturally delivered prompts may motivate stronger conceptual development than those read from the page.

We were also interested in whether electronic books, which can adapt to children's responses, can mimic the prompting and feedback provided by adults. One prior study with video indicated that video story prompts were not as effective at supporting comprehension when provided by an on-screen actress as when provided by a coviewing parent (Strouse, O'Doherty, & Troseth, 2013). However, these video prompts were not responsive to the child, as the video continued to play regardless of the child's actions. New technologies make adaptive prompting accessible to young children. Would electronic book prompts, which are dependent on the child's tap, be a better mimic for the type of responsiveness that is present in effective adult prompting?

Finally, we were interested in whether there are certain children for whom the source of prompting would matter more than others. For example, 4- to 6-year-olds who self-generate inferences while reading have better story comprehension skills (Kendeou, Bohn-Gettler, White, & van den Broek, 2008; Tompkins, Guo, & Justice, 2013). Perhaps children with robust language and comprehension skills would be more able to self-generate inferences and revise their knowledge regardless of how the prompts are provided. Given evidence that vocabulary scores correlate with comprehension skills (Florit, Roch, Altoè, & Levorato, 2009; Kendeou et al., 2008; Sénéchal, Ouellette, & Rodney, 2006) as well as predict them (Lepola, Lynch, Laakkonen, Silvén, & Niemi, 2012), we measured vocabulary as a potential moderator. We hypothesized that children with low vocabulary skills may be particularly influenced by the source of prompting because of the relatively lower level of comprehension they may achieve without the support of effective prompting.

In addition, we hypothesized that executive function skills could play a role in children's learning from an unmediated tablet interaction versus an adult-mediated reading experience. When children are given the freedom to proceed through an electronic book on their own, children with low inhibitory control may tap through the book quickly without much thought being given to the electronic prompts. Emerging research in this area has shown that there may be some link between children's impulsive tapping behavior with tablets and their inhibitory control, particularly during instructional messages (Russo, Duncan, & Troseth, 2015). However, when an adult specifically requests information from the child, this may motivate the child to put more effort into responding to the prompts. We hypothesized that whereas children high in inhibitory control would be able to self-regulate their own experiences and learn well from all books, those low in inhibitory control may benefit more from the adult-led conditions.

Method

Participants

Participants were 91 children age 4 (mean age = 4.47 years, *SD* = 0.26; 45 females) from a large metropolitan area in Canada. Most (90%) of the participants were recruited as they visited a local science center by recruiters who introduced themselves to families as they entered the children's section of the museum. Participants varied in the exhibits they had viewed in other sections or on prior visits to the museum. In an effort to increase our sample size, we recruited an additional 10% of participants from a database of participants compiled through advertisements, local street fairs, and child care centers. An additional 21 children were not included in the analyses because the child already had knowledge of camouflage (i.e., gave camouflage-based explanations [a score of 2, described in "Pretest"] for one or both pretest questions; $n = 10$), because the child had very low English language proficiency (i.e., more than 2 *SD* below the rest of our sample; $n = 3$), because of parental interference during reading or posttest questions ($n = 3$), because the child did not want to continue ($n = 3$), because the child had a diagnosed speech production delay ($n = 1$), or because of experimenter error ($n = 1$). Children read an electronic book about camouflage during which they were prompted to make predictions, were prompted to explain their predictions, and were provided with feedback about their responses. Participants were assigned to one of three conditions in which these prompts were (a) printed in and read by the book (*book-read;* 32 children), (b) printed in the book and read by the researcher (*researcher-read;* 28 children), or (c) not printed in the book and given face to face by the researcher (*extratextual;* 31 children). Data were collected over an 8-month period. We have no reason to believe that children who participated earlier in the study were different from children participating later in the study. For the first 6 months of data collection at the science center, assignment to condition was mostly sequential, as the three books were ready for data collection at different times (researcher-read first, then book-read, then extratextual). For the final 2 months of data collection, assignment to condition was fully random. Lab-based participants were all randomly assigned to condition. Participant exclusions were spaced equally across the 8 months of data collection and across conditions. Because of the fast-paced environment at the science center we did not prescreen participants; the study was open to all 4-year-old children.

Parents selected their child's ethnicity from a list copied from the Canadian Census form or could write in their own. The sample was ethnically diverse: Participants were identified by their parents as 30.7% White ($n = 28$ children) and 26.4% South and East Asian ($n = 24$). Remaining participants were 9.8% of multiple ethnicities ($n = 9$), 4.4% Middle Eastern ($n = 4$), 3.3% Latin American ($n = 3$), 3.3% Black ($n = 3$), 2.2% Aboriginal ($n = 2$), and 4.4% other ($n = 4$). Fourteen parents declined to respond to this question. The sample was also linguistically diverse: 31% came from monolingual

Table 1. Subsample Characteristics for Participants at the Science Center and Lab Locations.

Characteristic	*Science Center* n (%)	*Lab* n (%)
Total participants included	82	9
Condition assignment		
Book-read	30 (36.6)	2 (22.2)
Researcher-read	25 (30.5)	3 (33.3)
Extratextual	27 (32.9)	4 (44.4)
Parent education (highest achieved)		
High school diploma	6 (7.3)	1 (11.1)
College diploma	12 (14.6)	2 (22.2)
Bachelor's degree	27 (32.9)	1 (11.1)
Master's degree	19 (23.2)	3 (33.3)
PhD, MD, law degree	5 (6.1)	0 (0.0)
No response	13 (15.9)	2 (22.2)
Ethnicity		
White	26 (31.7)	2 (22.2)
Aboriginal	2 (2.4)	0 (0.0)
South and East Asian	23 (28.0)	1 (11.1)
Black	2 (2.4)	1 (11.1)
Latin American	3 (3.7)	0 (0.0)
Middle Eastern	4 (4.9)	0 (0.0)
Multiple	6 (7.3)	3 (33.3)
Other	4 (4.9)	0 (0.0)
No response	12 (14.6)	2 (22.2)
Language		
Monolingual	25 (30.5)	3 (33.3)
English primary bilingual	26 (31.7)	4 (44.4)
Other primary bilingual	31 (37.8)	2 (22.2)
Reasons for exclusion		
Passing pretest	8	2
Low English proficiency/language delay	4	0
Parental interference/child not interested	5	1
Experimenter error	1	0
Total participants excluded	18	3

English homes, 33% came from multilingual homes with English as their primary language of exposure, and 36% came from homes in which English was not their primary language of exposure. Parents were generally well educated, with a median and modal response of a bachelor's degree. The breakdown of these sample demographics across recruitment methods is presented in Table 1.

Materials

Electronic Picture Book

Children viewed an electronic picture book designed to teach children about camouflage. The book was based on that used by Ganea and colleagues (2011). The book contained a title page followed by 26 pages of text. The text provided basic information about color camouflage (e.g., "The lizard is the same colour as the grass. It's hard to see the lizard so the bird will fly away") and featured three different-colored lizards each on two backgrounds (one matching, one nonmatching). After some instructional text about each lizard, the text asked the child to "Put the lizard where it will be safe from the bird!" and gave two background options. Children were then asked to make a prediction: "Do you think the bird will see the lizard there?" This was followed by a request for an explanation as to why or why not. Finally, the child was told whether the bird saw the lizard and caught it or did not see the lizard and flew away, along with a reminder about why this was so (e.g., "The lizard and sand are both orange so the bird doesn't see the lizard").

Children could turn the pages of the book by touching an arrow in the top right-hand corner. On some pages, the lizards were interactive—children could drag or tap them at the request of the book. The lizard made a very simple and brief plop when moved, so children could hear that they were successful in making the movement. No other interactive features or hotspots were included in the book.

Children in all conditions heard the same text and prompts. In the book-read condition, the declarative text and child-directed prompts were both printed in the book and read aloud on each page. Prerecorded narration by the lead researcher played when the pages were turned. In the researcher-read condition, the same text and prompts were printed on the page and read live by the researcher. In the extratextual prompts condition, the same declarative text was printed in the book and read by the researcher. Pages including child-directed prompts were removed from the book, resulting in six fewer pages (two per lizard). Instead, the researcher turned to the child and presented the prompts in a face-to-face interaction. Thus, children *heard* the same language as in the researcher-read condition but *saw* only the declarative text printed in the book. Prompts occurred in a conversation-like way, as they would if an adult were providing additional prompts when reading a typical storybook.

Test Items

Children were pretested for their knowledge of camouflage using laminated pictures of animals: a hawk, a brown rabbit on a brown background (camouflaged), a white rabbit on a brownish-red background (not camouflaged), a green caterpillar on a green leaf (camouflaged), and a red caterpillar on a green leaf (not camouflaged).

After reading, children were tested using the same laminated photograph of the hawk along with plastic aquarium tanks with aquarium rocks and four plastic replica animals: two lizards and two turtles.

Vocabulary

Children completed the National Institutes of Health (NIH) Toolbox Picture Vocabulary Test. This computerized receptive vocabulary test presents children with four pictures and prompts them to select the picture that represents a given vocabulary word. It uses computer adaptive testing to adaptively generate appropriate questions for the child based on his or her responses. Children are assigned a score using item response theory.

Executive Function

Children completed an electronic version of the day/night task used by Gerstadt, Hong, and Diamond (1994). This task was not automated. Other than the electronic format of the pictures, Gerstadt and colleagues' procedures were followed.

Questionnaires

Parents completed a questionnaire that included demographic questions and questions about their child's media use, including use of books, electronic books, videos, and other media.

Procedure

Children participated either in a workshop room at the science center (90%) or in a testing room on campus (10%). Procedures were identical. Children sat at a child-size table with the experimenter.

Pretest

Children were first shown the picture of the hawk and told, "This is a bird that eats little animals. It is very hungry and looking for a rabbit to eat." Children were then presented with photographs of two rabbits, one camouflaged and one not, and were asked, "Which rabbit do you think the bird will eat, this one or this one?" Once children selected a rabbit, they were asked, "Why will the bird eat this one?" followed by "Why won't the bird eat this rabbit?" for the other rabbit. The same procedure was followed for a pair of caterpillars with a slightly different prompt, "Which caterpillar do you think is safe from the bird, this one or this one?" followed by requests for explanations. The side of the camouflaged animal was counterbalanced. Children were excluded from the study if they made a correct choice *and* gave a camouflage-based answer for either pretest question (e.g., "It is green like the leaves"). In all 10 cases, the camouflage explanation was given to the final question, "Which caterpillar do you think is safe?"

Reading

Children were then presented with the electronic book. Children in the book-read condition were told, "On each page, the book will read itself. When you are ready, you touch here to go to the next page." The experimenter then allowed the child to proceed through the book on his or her own without intervening. This was done to mimic the reality of how children would typically experience an electronic book in the absence of adult prompting.

Children in the researcher-read and extratextual conditions were told, "I am going to read to you what the book says on each page. Then when you are ready, you touch here to go to the next page." In these conditions the experimenter intervened if the child skipped pages and turned the page back to finish reading the text (or give prompts).

Posttest

After reading, children were presented with the hawk photograph again and told, "This bird is still hungry and now it's looking for a lizard to eat." For the *placement* questions, children were presented with an orange lizard and two tanks, one with orange rocks and one with green rocks, and asked, "Where should we put the lizard so it will be safe from the bird?" The prompt was then repeated using a brown turtle with brown and black tanks. After each placement question the experimenter asked the child to explain, "Why do you think the lizard will be safe here?" For the *choice* questions, children were presented with a camouflaged lizard (black lizard in a black tank) and noncamouflaged lizard (orange lizard in a brown tank) and asked, "Which lizard will the bird eat?" This was followed by a camouflaged turtle (green/green) and noncamouflaged turtle (brown/orange). After each choice question the experimenter asked the child, "Why do you think the bird will eat this one?" Whether children were asked the placement or choice questions first was counterbalanced. The camouflaged animal alternated between being placed on the right and left.

Vocabulary Test

Children completed the computerized Toolbox Picture Vocabulary Test. After the researcher read the test instructions to the child, she gave the child the choice of (a) controlling the mouse or touching the screen to respond or (b) pointing and having the experimenter control the mouse.

Executive Function Test

Children completed the day/night task using the procedures of Gerstadt and colleagues (1994). Children saw PowerPoint slides of a sun or a moon and were trained to say "day" when the moon picture appeared and "night" when the sun picture appeared. Children were then given two to four practice trials that included researcher prompts as needed ("What do you say for this one?") and feedback ("Good job!" or a reminder of the rules). They then completed 14–16 additional test trials without feedback. Slides were turned by the experimenter. For a more detailed description of how training trials transitioned to test trials, see Gerstadt and colleagues. To be considered scorable, children needed to pass at least one of the four practice trials; scorable children's latency to respond to the slides was coded.

Coding

Children's tank selections on the posttest questions were coded as correct or incorrect by the experimenter at the time of participation. The responses were also coded from video by a second coder who was blind to condition. Reliability was κ = .91. Discrepancies were resolved by a review of the videos by the first author.

Children's explanations for their selections on the posttest questions were coded by the experimenter as containing camouflage reasoning on a scale of 0 (no mention of color or visibility), 1 (incomplete response about color or visibility), or 2 (full camouflage reasoning). For example, explanations such as "He's hungry" or "It's nice and warm" were given 0 points, as they did not mention the color of either the lizard or the background or the bird's ability to see or not see the lizard. Explanations such as "Orange stones" or "The bird will see it" were given 1 point because they used the camouflage-related concepts of color or visibility but did not provide a complete explanation for how color was important for visibility (i.e., they referenced the color of the lizard or background alone—not both—or they did not give a reason for the lizard's visibility [in this case we considered that the child may be mimicking language from the book without understanding that color was the key factor for visibility]). Explanations such as "It's the same color as the lizard [referring to the tank background]" and "It's a different color so the bird can eat it" were given 2 points. The responses were also coded from transcripts by a second coder who was blind to condition. Reliability, assessed using a weighted kappa, was .92. Discrepancies were resolved by review by the first author.

Children's accuracy on the day/night pretest trials and latency to respond on the test trials were coded from video by a coder blind to condition and hypothesis. A second blind coder scored 30% of the videos. Reliability was κ = .87 (one disagreement) for whether children passed or failed the practice trials. For the test trials, the intraclass correlation coefficient was $r = .74$ for children's average latency to respond on accurate trials. The first coder's latencies were used in the analysis.

Results

Book-Reading Experience

Children on average spent about 5.5 min with the book. There was a significant difference by condition in time spent with the book, with children in the book-read group spending less time (M = 5:13, SD = 1:34) than children in the adult-led groups (adult-read, M = 5:55, SD = 0:39; extratextual prompts, M = 6:00, SD = 0:47), $F(2, 84) = 4.42$, $p = .015$, $\eta_p^2 = .097$. However, there was no correlation between time spent with the book and either outcome measure.

Children in the adult-led groups heard all of the text and prompts, as they were stopped by the experimenter from turning the pages early. This was done by the experimenter keeping a finger on the very top edge of the screen so that the child's tap to the next page would not be recorded or pressing the "back" page button and repeating the prompt. Children in the book-read group were allowed to go through the book on their own. Children in this group listened on average to the entire text on 18 of the 26 pages.

Forced-Choice Tank Questions

There were no differences in children's correct tank choices for lizard questions versus turtle questions, so their choices were collapsed for a score out of 2 on each question type (placement, choice). For each repeated measures analysis of variance (ANOVA) reported here, condition was included as a between-subjects variable and question set (placement, choice) as a repeated measure. Here we specified children's tank choices as the dependent variable. There was no effect of condition, $F(2, 88) = 0.86$, $p = .428$, $\eta_p^2 = .019$. However, there was a significant main effect of question type, $F(1, 88) = 12.56$, $p = .001$, $\eta_p^2 = .125$. Children scored significantly higher on the placement questions ($M = 1.63$, $SD = 0.68$), which were more similar to the training questions asked in the book than the choice questions ($M = 1.27$, $SD = 0.75$). There was no significant correlation between tank choices and time spent reading ($r = -.01$, $r = .05$) or number of complete pages listened to (book-read group, $r = .27$, $r = .17$).

Because children's experiences while reading were different across books (e.g., children in the book-read conditions could continue past the prompts without voicing any of their thoughts out loud), we did not look for condition differences in children's responses to the prompts during reading. However, overall patterns across all children in the study may be informative for considering how children's concepts change. Children's correct lizard placement for the three lizards during reading was high across all trials (78%–79%). Correct placement of the in-book lizards was related to children's accuracy in the placement trials at posttest, weakly at first and then more strongly for the second and third in-book lizards: first, $r_s(80) = .244$, $p = .027$; second, $r_s(79) = .457$, $p < .001$; third, $r_s(80) = .416$, $p < .001$. This suggests that children who tested correct placements later in the book were better able to transfer their knowledge outside of the book context to the posttest placement trials. Correct placement of the lizards in the book was not related to children's accuracy in the choice trials, which required children to choose the nonmatching background (the opposite of what they practiced in the book).

One might expect that correct *predictions* during reading would reveal deeper conceptual understanding and would be related to children's tank choices not only in the placement trials but also in the choice trials, which required reasoning about the concept in a way that was not presented during reading. Indeed, children's correct predictions on the third but not first and second in-book lizards predicted children's correct tank choices in both the placement trials and choice trials, indicating that correct predictions made later during reading were related to children's use of camouflage at posttest: placement trials, $r_s(71) = .242$, $p = .039$; choice trials, $r_s(71) = .309$, $p = .008$.

Camouflage Reasoning

Children's highest scored response during the question set was used. If children did not answer either question in the set correctly, they were given a score of 0, as this indicated that they did not correctly use camouflage reasoning. A repeated measures ANOVA with camouflage reasoning score as the dependent variable yielded no effect of condition. However, there was a significant main effect of question type, $F(1, 88) = 16.02$, $p < .001$, $\eta_p^2 = .154$. Children scored significantly higher on the placement questions ($M = 1.25$ of 2, $SD = 0.90$) than the choice questions ($M = 0.86$ of 2, $SD = 0.94$). There was no significant correlation between camouflage reasoning and time spent reading ($r = -.02$, $r = -.20$) or number of complete pages listened to (book-read group, $r = .11$, $r < .01$). There were, however, significant correlations between children's explanations during reading and children's explanations on both placement and choice trials at posttest: placement trial first lizard, $r_s(48) = .464$, $p = .001$; placement trial second lizard, $r_s(49) = .330$, $p = .018$; placement trial third lizard, $r_s(47) = .306$, $p = .032$; choice trial first lizard, $r_s(48) = .491$, $p < .001$; choice trial second lizard, $r_s(49) = .615$, $p < .001$; choice trial third lizard, $r_s(47) = .588$, $p < .001$.

Vocabulary

To test for the effect of vocabulary, we computed a median split and categorized children as low or high scorers. This was done because we did not expect the effect of vocabulary to be constant across conditions, as would be modeled with a covariate. Instead, we hypothesized a moderation, in which vocabulary would be more predictive of success in the book-prompt condition and less influential in the adult-prompt conditions. Vocabulary level was added to the repeated measures ANOVA as a between-subjects factor with tank choice as the dependent variable. There was again no main effect of condition and a main effect of question type, $F(1, 83) = 11.15$, $p = .001$, $\eta_p^2 = .118$. There was also a main effect of vocabulary level and a Condition × Vocabulary interaction: vocabulary level, $F(1, 83) = 4.66$, $p = .034$, $\eta_p^2 = .053$; Condition × Vocabulary interaction, $F(2, 83) = 3.21$, $p = .046$, $\eta_p^2 = .072$. Children with higher vocabulary levels outscored those with lower vocabulary levels across conditions. Follow-up tests indicated that this difference was nonsignificant for the two adult-led conditions and was significant and especially pronounced for the book-read condition, $F(1, 30) = 5.14$, $p = .031$, $\eta_p^2 = .146$.

A similar pattern emerged when the camouflage reasoning score was used as the dependent variable. There was again no main effect of condition and a main effect of question type, $F(1, 83) = 11.20$, $p = .001$, $\eta_p^2 = .119$. There was a main effect of vocabulary level and a Condition × Vocabulary interaction: vocabulary level, $F(1, 83) = 10.17$, $p = .002$, $\eta_p^2 = .109$; Condition × Vocabulary interaction, $F(2, 83) = 4.88$, $p = .010$, $\eta_p^2 = .105$. Children with higher vocabulary levels gave more camouflage-based responses than those with lower vocabulary levels across conditions. Follow-up tests indicated that this difference was nonsignificant within the two adult-led conditions and was significant and especially pronounced for the book-read condition, $F(1, 30) = 26.30$, $p < .001$, $\eta_p^2 = .467$.

Executive Function

To test for the effect of executive function, we again computed a median split based on latency to correct responses in the day/night task (for those children who passed the practice trials). Executive function split was entered into the repeated measures ANOVA as a between-subjects factor (along with condition; vocabulary was removed). Tank choice was the dependent variable. There was again no main effect of condition and a main effect of question type, $F(1, 67) = 6.95$, $p = .010$, $\eta_p^2 = .094$. There was no main effect of executive function, but there was an interaction between executive function and condition, $F(2, 67) = 6.69$, $p = .002$, $\eta_p^2 = .167$. Follow-up tests indicated that the executive function split was not predictive of correct tank choices in the book-read or adult-read conditions. However, children in the extratextual condition who had slower response times on the executive function task scored worse on the tank choices, $F(1, 20) = 10.71$, $p = .004$, $\eta_p^2 = .349$. When camouflage reasoning was entered as the dependent variable, there were no significant effects except the main effect of question type, $F(1, 67) = 10.91$, $p = .002$, $\eta_p^2 = .140$.

We were also interested in whether children whose executive function measure was unscorable using Gerstadt and colleagues' (1994) procedures were different from children who passed the practice trials. Unscorable children completed two practice cards, responded incorrectly or inconsistently to four training trials, and then subsequently responded incorrectly to the first two test trials. These children could have failed for a variety of reasons, of which we propose two that are potentially primary: (a) They understood the task but had extremely low inhibitory control such that they could not inhibit the incorrect response, or (b) they had very low verbal comprehension skills and did not understand the task. In either case, the unscorable children may have been a group of children who would particularly benefit from adult scaffolding. To examine this, we entered whether children were unscorable or scorable on the day/night task as a between-subjects variable and tank choice as the dependent variable. An interaction between failure and condition emerged, $F(2, 76) = 4.07$, $p = .021$, $\eta_p^2 = .097$. There were no other significant effects. Follow-up tests indicated no difference in the adult-led conditions, but children in the book-read condition who passed the practice trials scored significantly higher on tank choice than children who failed the practice trials, $F(1, 30) = 7.54$, $p = .010$, $\eta_p^2 = .201$. When camouflage reasoning was the dependent variable, there was no significant interaction but a main effect of question set and a main effect of day/night failure: question set, $F(1, 76) = 4.42$, $p = .039$, $\eta_p^2 = .055$; day/night failure, $F(1, 76) = 8.82$, $p = .004$, $\eta_p^2 = .104$. Those who passed the practice trials had significantly higher reasoning scores (placement, $M = 1.29$, $SD = 0.90$; choice, $M = 0.93$, $SD = 0.94$) than those who failed (placement, $M = 0.57$, $SD = 0.79$; choice, $M = 0.00$, $SD = 0.00$). Reasoning scores in the group who failed the day/night task exhibited a floor effect and thus were not viable for detecting condition differences.

Discussion

In this study we investigated whether an electronic picture book with high-quality prompts was effective in increasing children's use of appropriate camouflage-related reasoning about a predator–

prey situation. Overall we found the book to be an effective tool: 74% of children across conditions used camouflage-based reasoning at the posttest compared to 2% at pretest (two children scored 1 point at pretest; children who gave 2-point responses were excluded).

We also addressed whether electronic questioning was equally as supportive as questioning provided in person through reading or face-to-face prompting. We predicted that children may particularly benefit from adult-led face-to-face scaffolding, as this condition provided the strongest social cues to pedagogy. Children may rely on social information to help them determine what information is intended to be taught and learned, and direct prompting by adults is a familiar pedagogical situation. We also predicted that children may benefit from either type of adult-led prompting over book-read prompts, as these prompts were devoid of social cues entirely. In addition, children in the book-read condition had to structure their own book-reading session—they did not have the added benefit of an adult making them stop to hear the full prompts and then look expectantly to them for answers. We found no overall differences by source of prompting in children's use of the camouflage concept to choose the correct tank at posttest or in their camouflage-based reasoning scores.

Condition differences did emerge when we looked at particular groups of children. We hypothesized that children with low language and low executive function scores may particularly benefit from adult-led face-to-face scaffolding. The results showed this to be the case. There were no effects of vocabulary level for either adult-led condition, but there was a significant difference in conceptual learning in the book-read condition. Children with high vocabularies used more camouflage-based reasoning after hearing book-read prompts than children with low vocabulary scores. One possible explanation for this effect is that children with high vocabulary scores are better comprehenders in the absence of adult prompting (Lepola et al., 2012). As such, they may exhibit high comprehension regardless of the prompting source. They may be doing a lot of prediction making, evaluating, and revising of their concepts as they read, which could act as a protective factor to allow them to learn concepts well from many sources. In contrast, children low in vocabulary may be particularly sensitive to the source of scaffolding because they are more dependent on prompting to lead them to revise their concepts. They may be reliant on the structure of adult-led scaffolding, which they are somewhat obliged to listen and respond to, compared to book-read prompts that can be clicked past with little attention.

Condition differences also emerged when we split children by their level of inhibitory control. We hypothesized that children with low inhibitory control may tap through the book quickly, ignoring prompts and potentially scoring poorly in the book-read condition, in which they had the freedom to skip pages. However, children low in executive function did not do particularly poorly in this condition. When looking at children who produced scorable results on our executive function measure, we found a difference in conceptual learning only in the extratextual condition. In this condition, children with low executive function gave fewer correct tank choices than children with higher executive function. We hypothesize that children with low executive function did particularly poorly in this condition because they were asked to wait and converse with an adult before continuing through the book. Prompts that were delivered by the adult in this condition were delivered in lieu of two pages of text, which included tapping to turn the page and visual displays. Perhaps those low in inhibitory control lost patience listening to the adult and focused their attention on their desire to continue with the story.

Finally, condition differences also emerged in relation to whether children were able to pass the practice trials of the executive function task or whether they failed and were unscorable. We proposed two main reasons for failure—very low executive function and low verbal comprehension—either of which could be reasons why children would benefit from prompting. There were no differences in tank choice in the adult-led conditions, but in the book-read condition children who were unscorable selected the correct tanks much less often than those who were scorable. Children who were unscorable performed at the floor for camouflage-related reasoning across conditions, making an exploration of condition differences untenable.

Together these findings lend support to two main arguments: (a) Electronic books accompanied by high-quality prompts can be an effective source for developing many preschoolers' biological concept of camouflage, and (b) particular sources of prompting are more effective for supporting this type of conceptual learning in some groups of children.

Electronic books may be a good choice for teaching preschoolers because children enjoy them. For example, one study found that more preschoolers showed higher levels of engagement when reading an electronic than print book than vice versa (Chiong, Ree, Takeuchi, & Erickson, 2012). A child who is uninterested in learning from traditional paper books may be excited about using a tablet to explore the same material.

Our general finding that electronic books are an effective tool for learning is in line with a recent meta-analysis. Takacs, Swart, and Bus (2014) reviewed 29 studies and found that children had equivalent comprehension of multimedia stories and traditional stories that were scaffolded by adults. They argued that multimedia features could provide scaffolding that would mimic that which an adult provides. Because our prompts were founded on principles of conceptual change that have been applied successfully in other domains, such as physics (Vosniadou & Brewer, 1992) and math (Vosniadou & Vamvakoussi, 2006), and are generally discussed as applicable across domains (Carey, 2009), we expect that our findings may hold across other scientific and nonscientific domains of learning. Encouraging children to test their theories through prediction and explanation and adapt them when necessary in a context they find motivating and engaging is a basic formula for encouraging theory updating and revision.

Our findings also offer potential caveats. In the majority of cases, the pros and cons of interactive scaffolding may balance, such that the source of prompting does not make a significant impact on learning. However, when children are at particular risk for low comprehension, the source of scaffolding may be important. Although electronic books are motivating because of their form, they may not motivate children to reflect and evaluate their conceptual theories in the same way as human interactions. This could be for a few reasons: Social cues emphasize that information is pedagogical and should be learned; there is social pressure to respond contingently and effortfully; and, at least in this study, children are required to slow down and listen to all of the prompts. Teasing apart the importance of these aspects of in-person prompting is an important area for future research.

As a final note, Duke and Pearson (2002) suggested that one good way to support comprehension is to begin with adult-led comprehension strategies and gradually release the control of those strategies to students. Electronic media can act as a supportive intermediary, reminding children to implement strategies on their own. Once children are no longer at risk for low comprehension, electronic books with built-in scaffolding may be a fun and useful educational tool for conceptual learning that children can explore on their own.

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