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Sins of omission: Children selectively explore when teachers are under-informative

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ABSTRACT

Do children know when people tell the truth but not the whole truth? Here we show that children accurately evaluate informants who omit information and adjust their exploratory behavior to compensate for under-informative pedagogy. Experiment 1 shows that given identical demonstrations of a toy, children (6- and 7-year-olds) rate an informant lower if the toy also had non-demonstrated functions. Experiment 2 shows that given identical demonstrations, six-year-olds explore a toy more broadly if the informant previously committed a sin of omission. These results suggest that children consider both accuracy and informativeness in evaluating others' credibility and adjust their exploratory behavior to compensate for under-informative testimony when an informant's credibility is in doubt.

1. Introduction

Much of what we know about the world comes from what others tell us. However, informants can be ignorant, mistaken, withholding, or even deceptive. Rather than indiscriminately accepting all socially communicated information, learners need to know whom to trust.

Detecting unreliable informants may be relatively easy when they are obviously wrong. Previous research shows that even young children distinguish informants who provide false information from those who provide accurate information, and preferentially learn from previously accurate informants (Birch, Vauthier, & Bloom, 2008; Jaswal & Neely, 2006; Koenig, Clément, & Harris, 2004; Koenig & Harris, 2005; Pasquini, Corriveau, Koenig, & Harris, 2007). For instance, preschoolers are more likely to accept a label for a novel object from an informant who previously labeled a familiar object correctly (e.g. calling a ball a ball) than from someone who labeled the familiar object incorrectly (e.g., calling a ball a shoe; Koenig & Harris, 2005). Children are also sensitive to indirect cues to informant reliability, including verbal and non-verbal cues suggesting ignorance or doubt (Birch, Akmal, & Frampton, 2010; Koenig & Harris, 2005; Sabbagh & Baldwin, 2001), differences in informants' expertise or specialized knowledge (Lutz & Keil, 2002; Sobel & Corriveau, 2010), and descriptions of informants' benevolent or malevolent intent (Dunfield, Kuhlmeier, & Murphy, 2013; Landrum, Mills, & Johnston, 2013).

However, in typical communicative contexts, outright lies are rare; nor do informants usually convey ignorance, uncertainty, or malice. Instead, there are more subtle forms of misinformation that may be harder to detect. Imagine, for instance, someone who says, "I have a sister" when he has four sisters. Although the testimony is logically true, the implication is that he has only one sister. Providing logically true testimony that induces a false belief in others is a *sin of omission*.

Recent work on inductive inferences in social contexts provides a formal account of how under-informative testimony can be actively misleading. When an informant is

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assumed to be knowledgeable and helpful, the learner expects the informant to choose evidence that is most likely to increase the learner's belief in the correct hypothesis. Thus pedagogically transmitted information imposes strong constraints on the learner's inference (Shafto & Goodman, 2008; Shafto, Goodman, & Frank, 2012). For instance, when a teacher demonstrates that a toy squeaks, the absence of evidence for additional functions strongly implies the absence of additional functions; otherwise, the teacher would have demonstrated them. Consistent with this account, when preschoolers saw a teacher who showed that a toy squeaks, children rationally inferred that it was the toy's only function and spent most of their time squeaking the toy, discovering few of its other functions (Bonawitz et al., 2011). By omitting information about additional functions of the toy, the teacher induced a false belief in the learner.

Do children know when people tell the truth, but not the whole truth? To evaluate under-informative testimony, one must recover the pragmatic meaning of what is conveyed and understand that it induces a false belief in the listener. Therefore, even though young children can successfully evaluate sins of commission (false testimony), the ability to recognize the misleading nature of omitted information may not emerge until later.

In this study, we ask whether children can evaluate, and even compensate for, under-informative pedagogy. In Experiment 1, we ask whether children rate teachers who omit relevant information about a toy lower than those who do not omit such information. In Experiment 2, we look at whether children track others' past history of informativeness and engage in compensatory exploration when a teacher's informativeness is in doubt. Because previous work suggested that children might not be sensitive to the pragmatics of omitted information before the age of six (Noveck & Reboul, 2008; Papafragou & Musolino, 2003), and because pilot testing suggested that children younger than six had difficulty using the rating scale, we focused on ages 6 – 7.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Forty-two children between ages 6 and 7 were recruited from a local children's museum and were randomly assigned to either "Teach 1/1" ($N = 22$, $M_{age}(SD) = 6.9$ (0.61)) or "Teach 1/4" ($N = 20$, $M_{age}(SD) = 7.0$ (0.64)) conditions. Fifteen additional children were dropped for failing to meet the inclusion criteria (see Results).

2.1.2. Materials

Two yellow, pyramid-shaped novel toys were constructed using foam board and electronic parts (see Fig. 1). One toy (henceforth One-Function Toy) had only one functional affordance (twisting a purple knob activated a wind-up mechanism) and the rest of the parts did not depress nor function as buttons. The other toy (Four-Function Toy) looked almost identical, but in addition to the purple knob, the toy had one button that activated LED lights, one that activated a spinning globe, and one that activated music. Hand puppets were used as the naïve learner and teachers. Children rated the teachers using a rating scale, which had a knob that slid horizontally along tick marks from 1 to 20. Five color-coded faces (from frowny to smiley) served as additional anchor points along the scale.

2.1.3. Procedure

All children were tested individually in a quiet room inside the museum. The experimenter first introduced the children to Elmo, a silly monster who does not know much about toys. She said, "We will watch some teachers as they teach Elmo about their toys. Then we will tell them how helpful they were in teaching Elmo, so that they can do a better job next time". She briefly explained the rating scale, and asked children to indicate where they'd place the knob on the scale if the teacher did a "very good job", "just okay", and "not a good job". All children were able to use the rating scale to provide the appropriate rank order for the three evaluations.

The experimenter then gave the children either the One-Function Toy (Teach 1/1 condition) or Four-Function Toy (Teach 1/4 condition) to play with. Children were allowed to explore the toy until they tried all parts of the toy. Thus all participants entered the study knowing whether the toy had one or four functions.

Children then saw the Toy Teacher puppet teach Elmo about the toy. The Toy Teacher's action was identical in both conditions: he said, "This is my toy. I am going to show you how my toy works", and turned the purple knob on the toy to activate the wind-up mechanism. The puppet maintained a neutral tone of voice throughout and his facial expression did not change throughout the experiment (see Fig. 2 for the puppet used as the Toy Teacher). After two demonstrations of the wind-up part, the participant was asked to rate the teacher on the rating scale. Then children saw two more teachers who taught about names of their toys. The Correct Teacher puppet called a plastic carrot "a carrot" and a rubber duck "a duck". The Incorrect Teacher puppet called a stuffed rabbit "a cow" and a plastic corn "a cup". The order of Correct and Incorrect teachers were counterbalanced. These additional ratings allowed us to (1) identify children who failed to understand the rating scale, and (2) calculate an adjusted score for the Toy Teacher calibrated to the child's own ratings of the Correct and Incorrect Teachers (see Results).

2.2. Results and discussion

Five children rated the Incorrect teacher the same as or higher than the Correct Teacher, suggesting that they did not understand the task instructions. Additionally, ten children primarily enjoyed sliding the knob on the scale and gave a 0 or 20 to all the teachers. These children were also excluded from the analysis.[1]

[1] All results remain significant even when these children are included ($N = 24$ in Teach 1/1, $N = 28$ in Teach 1/4).

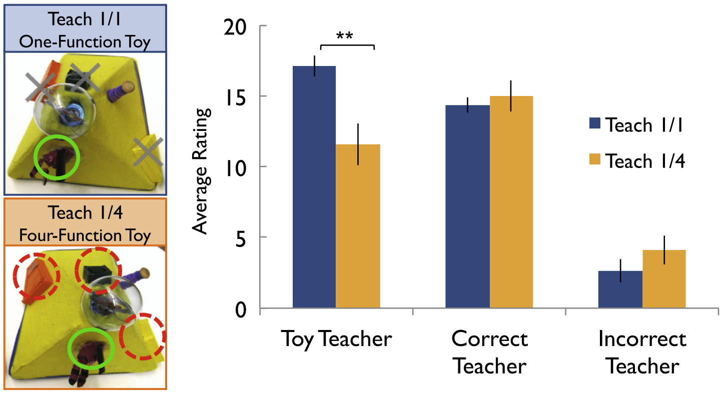

Fig. 1. Left: One-Function Toy and Four-Function Toy. The green circles indicate the functional affordance (wind-up mechanism) demonstrated by the Toy Teacher. Gray X's indicate non-functional affordances, and red dotted circles indicate the omitted functional affordances. Right: Results from Experiment 1. ($^{**}p < 0.005$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

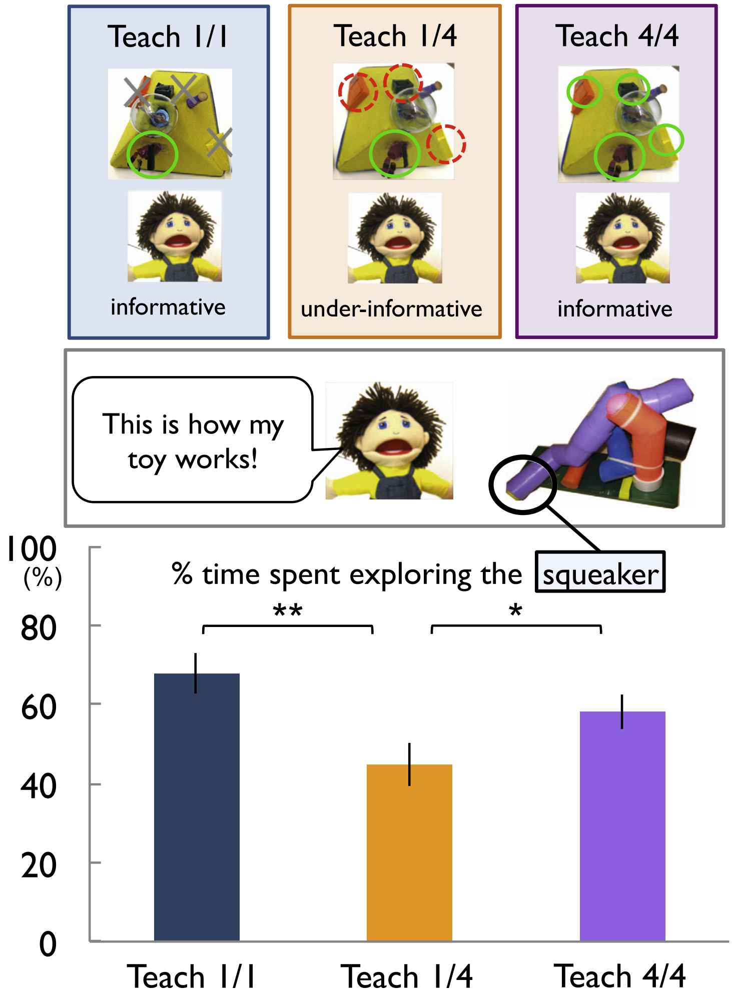

Fig. 2. Experiment 2 procedure and results. Top: Green and red dotted circles show functions that were demonstrated and omitted, respectively. Middle: In all conditions, Toy Teacher showed that the Test Toy squeaks. Bottom: Proportion of time (%) children spent playing with the demonstrated squeaker function during the first 30 s of play ($^{**}p < 0.005$, $^{*}p < 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Preliminary analysis confirmed that there were no differences in how long children explored the toy in the Teach 1/1 and Teach 1/4 conditions (Teach 1/1: M(SD) = 35.7 s (14.5) vs. Teach 1/4: M(SD) = 43.2 s (17.4); $t(39) = -1.49$, $p = ns$), or how they rated the Correct Teacher (Teach 1/1: M(SD) = 14.4(3.8) vs. Teach 1/4: M(SD) = 15.0 (4.6); $t(40) = 0.47$, $p = ns$), and the Incorrect Teacher (Teach 1/1: M(SD) = 2.6(2.6) vs. Teach 1/4: M(SD) = 4.1 (4.9); $t(28.5) = -1.25$, $p = ns$).

Then we looked at children's ratings for the Toy Teacher. In the Teach 1/1 condition, the Toy Teacher's demonstration of the wind-up mechanism was both accurate and complete. By contrast, the identical demonstration in the Teach 1/4 condition was accurate but incomplete. Thus although children saw the same demonstration in both conditions, we predicted that children would rate the Toy Teacher lower in the Teach 1/4 condition than in the Teach 1/1 condition.

As predicted, children in the Teach 1/4 condition rated the Toy Teacher significantly lower than children in the Teach 1/1 condition (Teach 1/1: M(SD) = 17.1(3.5) vs. Teach 1/4: M(SD) = 11.6 (6.7), $t(28.5) = 3.36$, $p = 0.002$; see Fig. 1). To confirm that the individual differences in children's references for rating did not affect our results, we calculated adjusted ratings for Toy Teacher using the following formula: Adjusted Rating = (Toy–Incorrect)/(Correct–Incorrect)). A value of 0 or lower indicates that the Toy Teacher was rated as low as, or lower than, the Incorrect Teacher; 1 or higher means that the Toy Teacher was rated as high as, or higher than, the Correct Teacher. Children's adjusted scores were significantly lower in Teach 1/4 than in Teach 1/1 condition (Teach 1/1: M(SD) = 1.45 (0.8) vs. Teach 1/4: M (SD) = 0.72 (0.4), $t(40) = 3.51$, $p = 0.001$).

In fact, children in Teach 1/4 condition rated the Toy Teacher lower than the Correct Teacher (11.6 vs. 15.0; $t(19) = 2.69$, $p = 0.014$), whereas those in the Teach 1/1 condition rated the Toy Teacher higher than the Correct Teacher (17.1 vs. 14.4; $t(21) = -2.12$, $p = 0.044$). This pattern also emerged in children's rank order of the three teachers (Toy Teacher, Correct Teacher, and Incorrect Teacher). While 14 of 22 (58.3%) children in the Teach 1/1 condition rated the Toy Teacher the highest of all three, only 5 of 20 (17.9%) children in the Teach 1/4 condition did so ($p = 0.016$, Fisher's Exact).

These results suggest that children are sensitive to under-informative pedagogy. Children understand that a teacher who provides accurate but incomplete information about a toy is less helpful than a teacher who provides accurate and complete information.

3. Experiment 2

Experiment 1 established that by around six years of age, children know when informants provide under-informative pedagogy by omitting relevant information. Do children also know whom to trust based on their past informativeness? If children's ratings simply reflect their transient impressions of informants' behavior, children may not care if someone had previously committed a sin of omission. However, if children track others' past informativeness and use it to guide their future learning, they might suspend their trust of informants who were under-informative in the past; instead, they might seek other ways to learn. In Experiment 2, we addressed this question by looking at children's exploratory behavior. As in Experiment 1, children first saw the Toy Teacher provide either under-informative (Teach 1/4) or fully informative (Teach 1/1) demonstrations of the yellow toy. Then children saw the same teacher demonstrate a single function of a novel toy.

We predicted that children who were previously taught by informative teachers would infer that the information about the novel toy was complete; because demonstration of a single function implies the absence of additional functions (see Bonawitz et al., 2011), children in these conditions would constrain their exploration of the new toy to the demonstrated function. By contrast, we predicted that children who were taught by the previously under-informative teacher would suspend such inference and explore the new toy more broadly.

Of course, children might explore the toy more broadly in the under-informative (Teach 1/4) condition than the fully informative (Teach 1/1) condition, not because they consider the informativeness of the teacher, but because they generalize the number of functions on the yellow toy to the number of functions on the new toy. However, if children are genuinely sensitive to the teachers' informativeness, they should trust a teacher who demonstrates four functions of the yellow toy when there are indeed four functions present. When that same teacher demonstrates a single function of the novel toy, children should infer that only a single function is present. We thus included a Teach 4/4 condition in Experiment 2, and predicted that children in the Teach 1/1 and Teach 4/4 conditions would be more likely to constrain their exploration to the demonstrated function than children in the Teach 1/4 condition.

3.1. Methods

3.1.1. Participants

Seventy-five 6-year-olds were recruited from a local children's museum and assigned to the Teach 1/1 ($N = 25$, M_{age}(SD) = 6.5 (0.28)), Teach 1/4 ($N = 25$, M_{age}(SD) = 6.4 (0.29)), and Teach 4/4 ($N = 25$, M_{age}(SD) = 6.4 (0.30)) conditions. Six additional children were dropped due to: parental interference ($N = 3$), experimental error ($N = 1$), not completing the procedure ($N = 1$), or showing no interest in the Test Toy ($N = 1$).

3.1.2. Stimuli

In addition to the yellow toys (One-Function and Four-Function Toy) and the Toy Teacher puppet from Experiment 1, we used another toy (henceforth Test Toy) made of PVC pipes attached to a wooden base. The toy had four non-obvious causal affordances (see Fig. 2), including a yellow tube that generated a squeak sound when pulled out from a larger tube.

3.1.3. Procedure

The initial procedure was similar to Experiment 1. First, children explored either the One-Function Toy (Teach 1/1 condition) or the Four-Function Toy (Teach 1/4 and Teach 4/4 conditions) to discover how many functions the toy had. Then children saw the Toy Teacher puppet teach Elmo (the naïve learner) about the toy. In the Teach 1/1 and Teach 1/4 conditions, the Toy Teacher demonstrated just one function (the wind-up part) of the yellow toy; in the Teach 4/4 condition, he showed all four working parts of the toy.

Then the experimenter introduced the new Test Toy. She told the participant that it is also the Toy Teacher's toy, and that he would show the child and Elmo how it works. His demonstration was identical in all conditions; he said, "This is also my toy. I am going to show you how my toy works" and pulled out a yellow tube from a larger purple tube to generate a squeak sound. After two demonstrations, children were allowed to freely explore the Test Toy for as long as they wanted, for up to 3 min.

3.2. Results and discussion

We predicted that even though all children saw identical demonstrations of the Test Toy, children's play with the toy would be affected by the teacher's past informativeness. In the Teach 1/1 and Teach 4/4 conditions where the teacher was fully informative about the first toy, children should trust the teacher; thus they should infer that the second, novel toy (Test Toy) has only the demonstrated function and should focus on playing with the demonstrated part of the Test Toy (the squeaker). In contrast, in the Teach 1/4 condition where the teacher was under-informative, children should mistrust the teacher and explore the Test Toy more broadly.

We were interested in the extent to which the children constrained their exploration consistent with the teacher's demonstration. Thus we coded the proportion of time children spent playing with the demonstrated function (the squeaker) relative to the time spent exploring the rest of the toy. To match for overall play time across participants, we focused our analysis on the first 30 s of play although we also looked at how children distributed their play over their entire play time (all but 3 of the 75 participants played for at least 30 s).[2] All data were coded by a trained coder blind to conditions. Because we had a priori hypothesis about the pattern of results across the three conditions, we used planned linear contrasts (see Bonawitz et al., 2011) by applying the weights 1, −2, and 1 for the Teach 1/1, Teach 1/4, and Teach 4/4 conditions, respectively.

There was no difference in how long children played with the Test Toy across conditions (Teach 1/1: M(SD) = 112.9(67.1), Teach 1/4: M(SD)=102.9(47.4), Teach 4/4: M(SD)=106.6(58.5), $p = ns$). However, the proportion of time children spent exploring only the demonstrated part of the toy differed significantly across conditions both during the first 30 s (Teach 1/1: M(SD) = 0.68(0.26), Teach 1/4: M(SD) = 0.45(0.27), Teach 4/4: M(SD) = 0.58 (0.22), $t(72) = 2.94$, $p = 0.004$; See Fig. 2) and the entire play period (Teach 1/1: M(SD) = 0.59(0.25), Teach 1/4: M(SD)=0.40 (0.24), Teach 4/4: M(SD) = 0.46(0.20), $t(72) = 2.19$, $p = 0.032$). Planned comparisons showed that children in the Teach 1/4 condition spent significantly less time with the squeaker during the first 30 s than did children in Teach 1/1 condition ($t(48) = 3.07$, $p = 0.002$; one-tailed) and Teach 4/4 condition ($t(48) = 1.88$, $p = 0.033$; one-tailed). There was no significant difference between the Teach 1/1 and Teach 4/4 conditions ($t(48) = 1.29$, $p = ns$).

As noted, children in the Teach 1/4 condition might have explored the test toy more broadly simply because they had just played with a multifunction toy (whereas children in the Teach 1/1 condition had played only with a single function toy). However, the results of the Teach 4/4 condition rule out this possibility. Children in the Teach 4/4 condition constrained their exploration to the demonstrated function just like in the Teach 1/1 condition, suggesting that children's play indeed reflects the teacher's informativeness rather than children's experiences with the previous toy. Thus by six years of age, children keep track of others' informativeness; when an informant's credibility is in doubt, children engage in compensatory exploration.

4. General discussion

Across two studies, we have shown that children care not just about whether information is true or false but also how informative it is. In Experiment 1, children recognized when teachers provided under-informative evidence. Given identical demonstrations, children rated under-informative teachers lower than fully informative teachers. In Experiment 2, children used teachers' past informativeness to guide their own behavior; when the teachers' informativeness was in doubt, children explored more broadly.

Importantly, not all omissions of information are bad. Both in formal education and in everyday communicative interactions, informants routinely skip information already known to the learner (e.g., the Toy Teacher did not say the toy was yellow), as well as information that is too complicated or unnecessary for the learner (e.g., neither did he say the toy was operated by two 1.5-volt alkaline batteries in parallel configuration). Informants also provide just a subset of highly generalizable information when the extension can be readily inferred (e.g., parents label a few objects as "cups" for a toddler rather than repeating this for every cup the child encounters). In some cases, omission can even be informative in itself. As noted, when preschoolers are shown just a single function of a toy, they infer that the toy has only one function, even if the teacher does not explicitly assert that no other functions are present (Bonawitz et al., 2011). Relatedly, children who are asked to choose a face "with glasses" prefer a face with glasses and no hat to a face with glasses and a hat; presumably if the speaker had meant the latter, she would have mentioned the hat (Stiller, Goodman, & Frank, 2011).

Given this, how do children accurately evaluate various instances of omission? To treat omission as a sin, children must know when information is misleading. If children already know the true state of the world (as in the current study where they knew the yellow toy's functions),

[2] We used the percentage of time spent playing with the squeaker to include the 3 children who played for slightly less than 30 s (between 25 and 30 s); using the raw time in seconds does not change the statistical results.

children can compare what they know with what a naïve learner might infer given the informant's instruction. If the informant could have provided more information but did not, then the informant has committed a sin of omission. Therefore, recognizing and evaluating under-informative pedagogy requires integrating information about the state of the world, with mental state inferences about what a learner might conclude given the information from the teacher. If the child is either unaware of the true state of the world or unable to understand what, other than the truth, a learner might infer from the teachers' information, then they may fail to recognize omission as a sin.

Thus sins of omission are closely related to violations of *Gricean Maxim of Quantity*, which states that a speaker should be as informative as required in communicative contexts (Grice, 1975; Horn, 1984). Prior studies on conversational pragmatics have shown that even school-aged children often fail to reject under-informative utterances (Barner, Brooks, & Bale, 2011; Noveck & Reboul, 2008; Papafragou & Musolino, 2003). This difficulty has been demonstrated with both non-scalar expressions (e.g., judging "the monkey ate the apple" as acceptable when the monkey ate the apple and the orange) as well as scalar expressions (e.g., judging "the monkey ate some fruit" as acceptable when the monkey ate all the fruit). If these results reflect genuine pragmatic incompetence, our results would seem puzzling.

A possible resolution comes from more recent studies on linguistic implicature. By using either clearer examples of omitted information, or more sensitive measures of children's evaluations, these studies report findings that are consistent with our results. For example, given a picture of a cow, a cat, and a dog sleeping, 4-year-olds do not reject "*only some* of the animals are sleeping" as a description of the scene; however, they do successfully reject an equivalent statement "*only the cat and the dog* are sleeping" (Barner et al., 2011). Furthermore, 5-year-olds who fail to reject under-informative informants when given a binary choice can distinguish between fully vs. under-informative statements when given a three-point-scale (Katsos & Bishop, 2011).

In the current study, children discovered all functions of the yellow toy so that they could easily represent what the Toy Teacher could have shown. We also used sensitive, continuous measures (like the 20-point rating scale and children's exploratory play) to capture children's evaluations and inferences. Our results are thus consistent with the recent developmental work suggesting that under these conditions, children successfully draw pragmatic implicatures at younger ages than previously believed. Although we have focused on children around 6 years of age due to various task demands, it would be interesting if even younger children show similar competence.

This work also suggests important links between linguistic pragmatics and inductive inferences in social contexts more generally. Regardless of whether information is conveyed linguistically or via goal-directed actions, children can draw inferences that go beyond the literal interpretation of information. Furthermore, when the information is logically true but pragmatically misleading, children accurately evaluate the informant. We hope that future work will shed light on the common cognitive processes underlying these inferences in various contexts, and will provide formal models of the cognitive mechanisms that allow learners to flexibly use teachers' informativeness to learn about the world.

In particular, we note that a teacher may be under-informative for a wide range of reasons. Our current study does not speak to the nature of the attributions children might have made when the teachers failed to be informative. To list just a few possibilities, the teacher might have been under-informative because he had a limited knowledge about the world (he was ignorant or had a false belief about the toy), because he had a poor understanding of the learner (he underestimated the child's abilities, or he overestimated what the child already knew), because of his particular circumstances (he was in a hurry), or because of his moral character (he was deceptive). The particular attributions children make should affect both their inferences and future behavior. If, for instance, children believe the teacher omitted information because he was in a hurry, they may be more likely to trust him in the future than if they believe the omission was due to his ignorance or deceptive intent. Studying the representations and the inferential processes that underlie children's evaluations of informants remains a rich area for future work. In the current study, we show that even in typical pedagogical contexts where informants are assumed to be knowledgeable and helpful, children accurately evaluate omission of information and adjust their behavior when learning from under-informative teachers.

Much of early learning occurs in social context. Children acquire much of what they know from information provided by others. In particular, information selected by knowledgeable, helpful agents can place strong inferential constraints that make human learning so fast, so robust, yet so accurate (Bonawitz et al., 2011; Gweon, Tenenbaum, & Schulz, 2010; Shafto & Goodman, 2008). Thus in learning from others, it is important to know whom to learn from; the accuracy of such inferences hinges on the quality of the information. Even in childhood, social evaluation and learning depend not just on how attractive, friendly, or powerful other agents are, but also on an understanding of how likely agents are to provide information that supports accurate learning. Critically, such evaluations, in turn, affect what and how children learn. When we teach children about the world, we also teach them something about ourselves.

H.G. and L.S. designed the study. Testing and data collection were performed by H.G., H.P. (Experiment 1), and J.P. (Experiment 2). H.G. analyzed the data. H.G. and L.S. wrote the paper. All authors approved the final version of the paper for submission.

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