Didn't know, or didn't show? Preschoolers consider epistemic state and degree of omission when evaluating teachers

Ilona Bass (ilona.m.bass@rutgers.edu)[1], Elizabeth Bonawitz (elizabeth.bonawitz@rutgers.edu)[1], Hyowon Gweon (hyo@stanford.edu)[2]

[1] Department of Psychology, Rutgers University, Newark, NJ 07102

[2] Department of Psychology, Stanford University, Stanford, CA 94305

Abstract

The ability to recognize and evaluate reliable informants is a critical skill for effective social learning. Building on prior work showing children's sensitivity to informants who omit relevant information, here we asked whether children's teacher evaluations incorporate information about 1) the epistemic state of the teacher, and 2) the amount and value of information taught. Preschool-aged children rated informants who taught learners about a novel toy with four functions; we systematically varied the number and value of functions the teachers knew and taught. Our results indicate that children exonerated unintentional omissions of teachers who had incomplete knowledge, and provided graded ratings based on the degree of omission. These findings are consistent with the predictions of prior computational work, and suggest that the ability to reason about others' knowledge plays an important role in children's inferences about others' efficacy as informants.

Keywords: cognitive development, pedagogy, social learning

Introduction

Young children rely heavily on others for their learning. Although children readily explore and learn from their own experience (Schulz, 2012; Bonawitz, van Schijndel, Friel, & Schulz, 2012; Stahl & Feigenson, 2015), pedagogy is a powerful, effective way to learn about the world. Recent research suggests that children do more than simply absorb and accumulate information from others; they actively modulate their inferences depending on the social context (Bonawitz et al., 2011), and selectively approach others to request information when help is needed (Gweon & Schulz, 2011; Goupil, Romand-Monnier, & Kouider, 2016). However, learning from pedagogy comes with an inherent hazard: being misinformed. Informants may vary in quality – some may be wrong, ignorant, or even deceptive. Thus, the ability to detect and evaluate unhelpful informants is critical for accurate learning. How do young children face this challenge?

Prior research has found that children avoid learning from informants who provide inaccurate information (e.g., Birch, Vauthier, & Bloom, 2008; Jaswal & Neely, 2006; Koenig, Clément, & Harris, 2004; Pasquini, Corriveau, Koenig, & Harris, 2007). Recent studies further suggest that young children recognize and evaluate a more subtle form of misinformation: providing accurate yet insufficient evidence. Given a teacher who presented one function on a toy, children rated the teacher as more helpful when the toy only had one function than when it had four (i.e., when the teacher omitted 3 of the 4 functions; Gweon, Pelton, Konopka, & Schulz, 2014a; Gweon & Asaba, in press). Children as young as four show this sensitivity, although they successfully evaluate uninformative teachers only after observing a fully informative teacher (Gweon & Asaba, in press). Thus by the preschool years, children expect teachers to be accurate and fully informative, and penalize those who violate these expectations.

This early-emerging sensitivity to teacher informativeness raises important questions about *how* children make these evaluations: What are the representations and inferences that allow children to distinguish helpful and less helpful teachers? One possibility is that children learn sets of rules and exceptions that allow them to recognize and avoid undesirable teachers. Prior findings suggest that young children are biased towards trusting adult informants, and may even continue to trust them after discovering their unreliability (Jaswal, Croft, Setia, & Cole, 2010). Children may also acquire a set of rules akin to Gricean Maxims (Grice, 1975), which prescribe that a helpful, cooperative communicator should provide accurate and relevant information in the right amount. If children are simply using learned heuristics or rules to evaluate informants, it may be difficult for them to make nuanced, context-specific judgments of informant quality, particularly in novel situations. However, another possibility is that these evaluations arise from sophisticated inferences about teacher informativeness; by understanding how unobservable mental states of others (e.g., informants' intent or knowledge) can influence their teaching behaviors, children can draw much more flexible and accurate informant evaluations even in novel contexts.

Previous work on Theory of Mind and moral reasoning suggests that young children readily interpret others' observable actions in light of their unobservable mental states: They evaluate others' actions based on their outcomes and on the actor's underlying intent, exonerating accidental harms (e.g., Cushman, Sheketoff, Wharton, & Carey, 2013; Wellman, Cross, & Watson, 2001; Nelson, 1980; Baird & Astington, 2004). Furthermore, even toddlers exonerate an agent who refused to help another person when the agent was incompetent and thus unable to help the requester (Jara-Ettinger, Tenenbaum, & Schulz, 2015). Given prior work on children's ability to consider others' mental states in evaluating others, here we ask whether children can consider informants' knowledge and their competence in evaluating their teaching.

Prior computational work describes teacher-learner interactions as based on a set of mutually constraining inferences. The teacher considers the learner's knowledge to select the evidence that would maximally increase the learner's belief in the correct hypothesis. The learner updates his beliefs with the assumption that the teacher is knowledgeable and intends

to provide the best information for the learner (Shafto, Goodman, & Frank, 2012; Shafto, Goodman, & Griffiths, 2014). In this framework, a teacher can be evaluated based on how she samples information for the learner, and what the learner can infer from the information.

This allows us to consider two key hypotheses about what might influence children's evaluations of teachers. Consider a teacher demonstrating a device with four functions (some interesting, some humdrum) to a naïve learner. How might a rational observer evaluate the teacher, based on what she demonstrates? First, we might predict that an evaluation of an informant is sensitive to the epistemic state of that informant. For example, consider two teachers, each of whom demonstrates just one of the four functions. One teacher knows that the device has four functions, but the other only knows about the one function she demonstrated. While the learner only learns about one of the four functions in both cases, we might be more inclined to pardon the teacher who didn't know about the additional functions: The ignorant teacher demonstrated everything she knew, and may thus be considered a better teacher than the knowledgeable informant who omitted information. We refer to this as the *epistemic pardon hypothesis*.

Our second hypothesis pertains to the quality of the taught information. A teacher who knows all four functions of a device will be *most helpful* if she demonstrates all four, and *least helpful* if she demonstrates none. Extending this reasoning to partial demonstrations, we would predict evaluations to be modulated by the degree of omission: Even when two teachers both omit information, a teacher who demonstrates two functions is still better than someone who showed just one. Further, if the functions differ in their value (e.g., how interesting they are), we might also expect an effect of the value of demonstrated functions: A teacher who demonstrates two high-value functions and omits two low-value functions would be better than someone who does the opposite. We refer to these predictions as the *quality-of-omission hypothesis*.

Recent computational work has formalized the two hypotheses posited above, and shown that adults' evaluations of various teachers are highly consistent with these hypotheses (Bass, Hawthorne-Madell, Goodman, & Gweon, 2015). When adults evaluate informant quality, they readily incorporate information about a teacher's epistemic state, as well as the amount and the value of taught information. Adults' informant evaluations are thus likely based on abstract representations of others' minds rather than a set of rules that dictate what a teacher should or should not do.

Some prior work suggests that children's evaluations of teachers also depend on abstract representations of knowledge states rather than simple heuristics. For instance, children show increased exploration of a toy following a teacher's demonstration of that toy if the teacher had previously committed a sin of omission (Gweon et al., 2014a), suggesting that children use concrete demonstrations to infer abstract qualities of teachers' quality, and adjust their inferences accordingly. Children also understand that omission isn't always bad: Given a toy with 20 buttons but only 3 that are functional, children prefer a teacher who shows just the 3 functional buttons (as opposed to the one who additionally shows the 17 inert buttons), *if* the learner already expects only a few of the buttons to work (Gweon, Shafto, & Schulz, 2014b). Children thus readily consider *learners'* epistemic states to evaluate teacher helpfulness, and even judge omission as beneficial when partial demonstration is sufficient. However, these studies leave open a critical question: Can children consider the *teacher's* epistemic state in evaluating the helpfulness of their teaching? Going beyond recognizing that teachers might not know everything (Jaswal & Neely, 2006), can children actually use this information to exonerate under-informative pedagogy? Because children are surrounded by many adults who are much more knowledgeable than they are, this may be a particularly challenging inference for young children.

Preschoolers' Evaluations of Teachers

In the current study, we investigate whether preschool-aged children's teacher evaluations reflect the underlying representations of teachers' knowledge and competence; in particular, we ask whether each of our two hypotheses (epistemic pardon, and quality-of-omission) – both of which are consistent with adults' teacher evaluations (Bass et al., 2015) – are also consistent with children's ratings of teacher quality. We showed children videos of five different informants who taught learners about a novel toy with four functions. We systematically varied the number and value of functions that the teachers knew and taught, and randomized the order in which the five teachers were seen with one caveat: All children first saw the teacher who knew and taught all four of the toy's functions, and were told that this was an example of excellent teaching. Our decision to anchor children's responses in this way was motivated by prior findings: First, children reliably rate teachers highly when they provide true and complete information (e.g., Gweon et al., 2014a; Koenig & Harris, 2005); second, although four- and five-year-olds' ability to evaluate under-informative teachers is limited, seeing an example of a fully informative teacher first allows them to successfully evaluate under-informative teachers (Gweon & Asaba, in press). These results suggest that such contextual support helps children attend more closely to dimensions of teacher informativeness. Since we are interested in children's ratings of several under-informative teachers relative to each other (and not to the fully informative teacher), we anchored children's ratings of this ideal teacher at the top of the scale.

Methods

Participants

Thirty-four children ($M_{\text{age}} = 60$ months, range $= 49 - 72$ months; 15 females) were tested at local preschools.

Materials

Rating Scale Children used a 0 to 20 point rating scale to evaluate teachers. Children placed a small circular magnet on

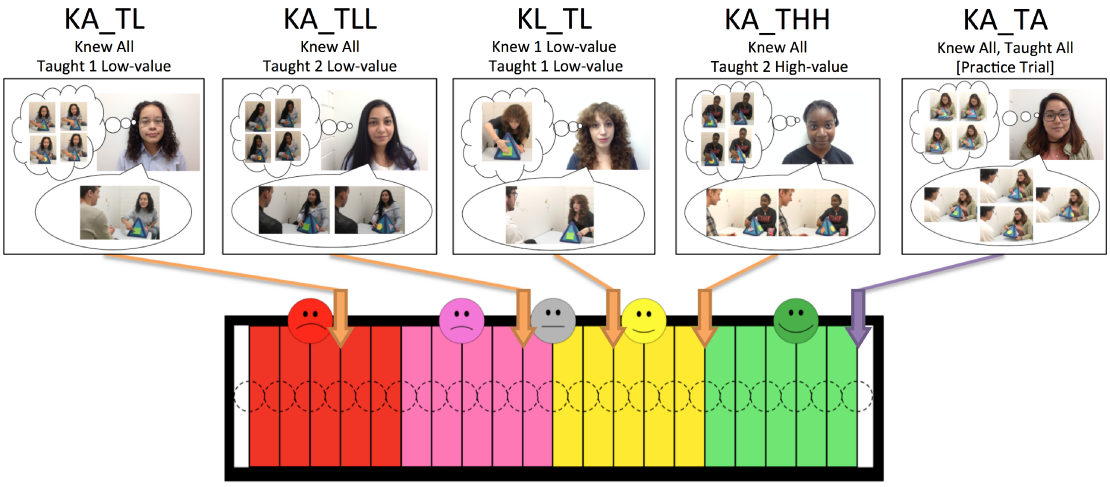

Figure 1: All children saw and rated the KA_TA teacher first. The order of the remaining four test trials was counterbalanced across children. Memory cues were adhered to the rating scale as children provided their ratings.

the scale to indicate how good they thought a teacher was.

Novel Toy The novel toy was a square pyramid covered in blue felt with four colorful buttons, each corresponding to a different function. Two functions were low-value: The toy could beep, and it could make a static-like noise. The other two functions were high-value: The toy could play clips of two different children's songs. The relative value of these functions were validated in a separate group of 10 children ($M_{\text{age}} = 66$ months, range $= 49 - 91$ months), who were asked to rate "how cool" each of the four functions were using the rating scale described above. The two songs ($M = 15.3$, $SD = 3.1$) were rated significantly higher than the beep and the noise ($M = 8.8$, $SD = 3.7$; $t(9) = 3.41$, $p = .008$), with no differences within the value pairs (p's $> .33$).

Teaching Videos Teaching videos were presented on a 15-inch MacBook Pro, and comprised two main phases. In the Exploration phase, the teacher sat down at a table on which the novel toy was placed and explored the toy's functions; then, a naïve learner suddenly entered the room, startling the teacher out of her exploration, and asked her to show him how the toy worked. In the Teaching phase, the teacher demonstrated to the learner some subset of the functions she had discovered during the exploration phase (details follow), after which she said, "That's how this toy works!" thereby clearly ending the demonstration.

There were five versions of the teaching videos, which varied based on the number and value of the functions that the teacher discovered and taught. In the Exploration phase, the teacher either discovered 1) all four functions, or 2) just the low-value "beep" function before the learner entered the room. In the Teaching phase, the teacher either taught: 1) all four functions, 2) both high-value functions, 3) both low-value functions, or 4) just one low-value function ("beep"). Crossing these two variables yielded five possible teaching scenarios: KA_TA, in which the teacher Knew All and Taught All; KA_THH, where she Knew All and Taught 2 High-value functions; KA_TLL, in which she Knew All and Taught 2 Low-value functions; KA_TL, where she Knew All and Taught 1 Low-value function ("beep"); and KL_TL, where she Knew 1 Low-value function ("beep") and taught it.

Memory Cues To help children recall precisely what each teacher knew and taught, we created small cards that depicted screenshots of the Exploration and Teaching phases from the teaching videos. Small arrows with adhesive backs were attached to each memory cue (see Figure 1).

Procedure

Frame Story & Rating Scale Training Children were told that they would be meeting some people who were in teaching school; the experimenter needed the child's help to figure out how good the different teachers were so that she would know how much more school the teachers needed. The experimenter then introduced the rating scale, and children were briefly trained on how to use it to indicate teacher quality. Children who failed this training did not proceed to the main task and were dropped from analysis (see Results).

Novel Toy Next, the experimenter introduced the novel toy, and encouraged children to try to figure out how it worked. After the child successfully pressed all four buttons, the experimenter noted that they now knew all about the toy. Children were then told that the other day, the teachers from the school had taught some new students about how the novel toy worked, and it was the child's job to watch them teach about the toy and figure out how good each teacher was at teaching.

Teacher Evaluations All children were first shown the KA_TA condition. Before watching the video, children were told that this teacher was all done with school, and was therefore already a good teacher. After watching the first video, children were shown the memory cue for the KA_TA teacher,

and were asked to provide a rating. Children who did not place the marker near the top of the rating scale were reminded that this teacher was already done with school. The experimenter adhered the memory cue's arrow to the rating scale where the child had placed the marker.

Children were then shown the remaining four teachers who, they were reminded, were still in teaching school; these constituted the four test trials. The order in which these four teaching scenarios were presented was completely counterbalanced, yielding 24 different orders. While the actors in the videos and the test conditions were fully counterbalanced with respect to each other, such that any potential effects of teaching condition could not be explained by personal characteristics of the actors, the order of the actors was always the same (e.g., "Liz" was always the first teacher, even though the first test condition varied between participants). After watching each video, children were shown the memory cue for the teacher they had just seen, and were asked to provide a rating. The experimenter adhered the memory cue's arrow to the rating scale where the child had placed the marker. Children who merely placed each teacher on the scale in the order of presentation (from most helpful to least helpful) were excluded from analysis. See Figure 1 for a schematic of the procedure for teacher evaluations.

Results

Prior to analysis, we dropped children who did not pass the rating scale training ($N = 1$), placed teachers in descending order on the rating scale as they saw them ($N = 7$), or gave all teachers the same rating ($N = 1$). One additional child did not want to continue playing after the first KA_TA trial. Our final sample therefore consisted of 24 children ($M_{age} = 60$ months, range $= 49 - 72$ months; 12 females).

We first asked whether children differentiated between the four teachers in the test trials. An omnibus repeated-measures ANOVA on children's ratings in these four trials revealed a significant main effect of condition ($F(3,69) = 3.50$, $p = .020$, $\eta_p^2 = .132$; see Figure 2). We therefore conducted followup analyses to investigate our two stated hypotheses.

Epistemic Pardon Hypothesis

To investigate the effect of the teacher's epistemic state on children's ratings, we compared the KA_TL condition to the KL_TL condition, thereby holding constant what the teacher taught and only varying what she knew. A paired-samples t-test revealed significant differences between the ratings of these two teachers ($t(23) = 2.58$, $p = .017$, $\eta_p^2 = .224$), with children giving higher ratings to the teacher who knew only one function ($M = 11.5$, $SD = 5.7$) than the teacher who knew all four functions but taught just one ($M = 7.8$, $SD = 5.4$).

We also looked at the number of children who placed the KL_TL teacher higher than the KA_TL teacher on the rating scale. Seventy-one percent of participants rated the KL_TL teacher higher than the KA_TL teacher; this proportion differed significantly from chance (50%, $p = .032$ one-tailed),

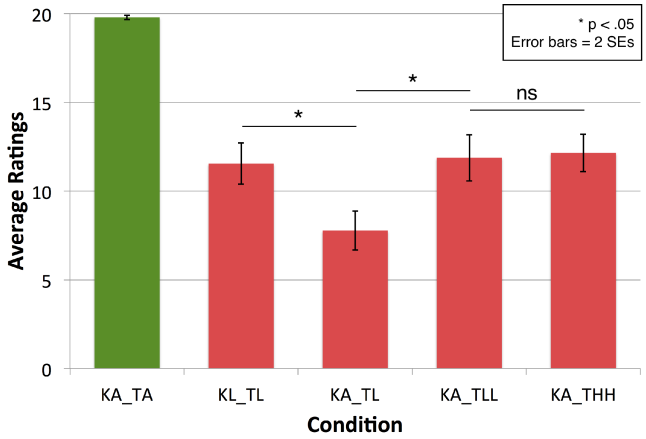

Figure 2: Average ratings for the KA_TA reference teacher and all four test conditions. Children rated the teacher who knew only one function (KL_TL) higher than the teacher who knew all but taught one (KA_TL), pardoning omission when it occurred for epistemic reasons. Children also showed sensitivity to the degree of omission, rating the teacher who demonstrated two low-value functions (KA_TLL) as better than the teacher who demonstrated one (KA_TL).

providing additional evidence that children considered teachers' epistemic states when making their evaluations, and were even able to exonerate bad teaching when it was explained by limited knowledge.

Quality-of-Omission Hypothesis

We explored the effect of the degree of teachers' omission of information on children's ratings with a paired-samples t-test, comparing the KA_TLL condition to the KA_TL condition (varying the number of functions taught while holding epistemic state and value constant). We again found significant differences ($t(23) = 2.54$, $p = .019$, $\eta_p^2 = .218$): Children gave higher ratings to the teacher who demonstrated two low-value functions ($M = 11.9$, $SD = 6.4$) than the teacher who demonstrated just one low-value function ($M = 7.8$, $SD = 5.4$). As before, we also compared the proportion of children who rated the KA_TLL teacher higher than the KA_TL teacher to chance. This binomial test neared significance ($p = .076$ one-tailed), with 67% of children rating the KA_TLL teacher higher than the KA_TL teacher.

Finally, we compared the KA_TLL teacher to the KA_THH teacher to examine the effect of information value on children's ratings. This paired-samples t-test was not significant ($p = .874$): Children did not differentiate between teachers who taught two high-value ($M = 12.1$, $SD = 5.2$) versus two low-value ($M = 11.9$, $SD = 6.4$) functions. Possible explanations for this null result follow in the discussion.[1]

[1] In an ongoing replication with adults, we are finding the same pattern of results as we did with children: Adults' ratings are influenced by the informant's knowledge state and the degree of information omission, but not by the value of the functions taught.

Discussion

Inspired by computational models of pedagogy and prior behavioral work with adults (e.g., Shafto et al., 2014; Bass et al., 2015), here we investigated how children make nuanced evaluations of helpful and unhelpful teachers; specifically, we asked whether children 1) exonerate partial teaching based on the teacher's epistemic state, and 2) provide graded evaluations based on the amount and value of information taught. We found that, like adults, preschoolers were sensitive to teachers' epistemic states, and accordingly pardoned informants who provided less information when teaching from limited knowledge. Children's ratings were also sensitive to the amount (but not the value) of information taught.

The results from our epistemic comparisons extend prior work showing that children prefer truthful teachers (Koenig et al., 2004; Koenig & Harris, 2005; Jaswal & Neely, 2006), and fully informative teachers (Gweon et al., 2014a; Gweon & Asaba, in press). They are also consistent with more recent findings on children's ability to consider learners' epistemic states (Gweon et al., 2014b) in evaluating teachers. However, our findings are somewhat surprising in light of the idea that many explicit Theory of Mind (ToM) skills are just developing between the ages of three and five (Wellman et al., 2001). Without explicit information about what the teacher knew, preschoolers were able to 1) *infer* her epistemic state by observing her exploration, and 2) *use* this representation to pardon her "sin of omission".

This finding thus raises important questions about the relationship between the development of ToM reasoning and social evaluation in pedagogical contexts. If ToM does in fact modulate children's teacher evaluations, children may become more adept at selecting from whom to learn throughout their preschool years. Indeed, Jaswal et al. (2010) found that three-year-olds are almost indiscriminately trusting of informants, while older children are more wary of possible misinformation. It would be interesting to ask whether children who are better at ToM reasoning also consider teachers' epistemic states more readily, leading them to be more willing than children with less proficient ToM abilities to exonerate teachers who were unintentionally under-informative. Critically, given recent findings on the relationship between ToM and children's own teaching skills (Bass et al., in press), such results would support important links between theory of mind, pedagogical skill, and teacher evaluations.

Note that although children did exonerate the KL_TL teacher relative to the KA_TL teacher, no under-informative teacher was rated as favorably as the informant who knew and taught all four of the toy's functions. Intuitively, this makes sense: Children's ratings of an informant's helpfulness will reflect, among other things, how well a learner learned as a consequence of the informant's teaching. Thus while the KL_TL teacher did the best she could given what she knew, she was still not as good of a teacher as the KA_TA teacher because she failed to discover information that could have been useful for the learner. This intuition also naturally arises in adults' teacher evaluations, and is consistent with Bayesian models of pedagogical reasoning (e.g., Bass et al., 2015). Are there circumstances under which under-informative teaching can be fully exonerated? In ongoing work, we are exploring whether the degree to which children exonerate under-informative teachers is modulated by contexts that explain away the teacher's failure to discover relevant functions and resultant lack of knowledge (e.g., a broken toy).

Our results also show that children did not penalize all omissions equally. Even though all teachers were under-informative, children were sensitive to the "degree of omission," giving lower evaluations to teachers who provided less information. This extends prior work showing that children distinguish fully informative teachers from those who were vastly under-informative (Gweon et al., 2014a; Gweon & Asaba, in press), and further suggests that children's evaluations of under-informative teachers are based on a more nuanced understanding of teachers' behaviors than a simple binary judgment. This leaves open questions about the nature of the mechanisms that underlie sensitivity to informant quality more generally: How early do they emerge? What other factors can children incorporate into their informant evaluations, and how do these change as children develop?

Our work adds to the growing body of literature on children's ability to draw pragmatic inferences from others' behaviors in both verbal and nonverbal communication. Recent work has demonstrated intriguing parallels between children's evaluations of pedagogical informants and their ability to draw scalar implicature (Gweon & Asaba, in press). Given prior work on scalar implicature that reveals children's ability to evaluate infelicitous uses of quantifiers (Barner, Brooks, & Bale, 2011; Katsos & Bishop, 2011), our results further suggest that children as young as four might have the necessary prerequisites for considering the "degree of sin" in infelicitous scalar expressions (e.g., it is worse to say that the boy drank "a bit" of milk than to say he drank "some" milk, when really he drank almost all the milk in the cup).

Finally, we note that children's ratings in the current study were not moderated by the value of the demonstrated functions: Children rated a teacher who chose to show the two lower-value functions just as highly as the teacher who showed two higher-value functions. These results differ from adults' sensitivity to information value in a highly similar paradigm (Bass et al., 2015). There are several possible explanations for this null finding. First, the relative value of the toy's functions in our study may not have been salient enough to elicit this difference. While we did validate the functions' values in a separate group of participants, those children were explicitly asked to compare and consider the functions' "coolness"; for children in the current study, these subtle value differences may not have been conspicuous enough to differentiate teachers who taught the songs versus the noises. A second possibility is that the ability to consider the value of information in service of making pedagogical evaluations does not emerge until later in development. This would suggest that

although children show remarkable ability in evaluating others, there may be other important factors that young children fail to consider. Third, it is possible that children are capable of considering information value (and that the functions' values were sufficiently salient in our task), but that children spontaneously attributed a reason for *why* the informant selected these functions; for instance, perhaps the low-value teacher really liked those functions, or thought they would be more important for the learner to know. Future work could tease apart these hypotheses to identify the role of information value in children's informant evaluations.

As we have discussed, there are many unanswered questions concerning the nature of children's reasoning about pedagogical informants that our results do not directly address. Nevertheless, along with prior work, our findings suggest that young children do have abstract representations of what it means to be a good teacher. Understanding the development of children's epistemic trust and its relationship to their growing ability to reason about others' minds will provide further insight into the cognitive mechanisms that support the uniquely human abilities to learn from and teach others.

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