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Four-year-olds incorporate speaker knowledge into pragmatic inferences

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Abstract

Human communication relies on the ability to take into account the speaker's mental state to infer the intended meaning of an utterance in context. For example, a sentence such as 'Some of the animals are safe to pet' can be interpreted as giving rise to the inference 'Some and not all animals are safe to pet' when uttered by an expert. The same inference, known as a *scalar implicature*, does not arise when the sentence is spoken by someone with partial knowledge. Adults have been shown to derive scalar implicatures in accordance with the speaker's knowledge state, but in young children this ability is debated. Here, we revisit this question using a simple visual world paradigm. We find that both 4- and 5-year-olds successfully incorporate speaker knowledge into the derivation of scalar inferences. However, this ability does not generalize immediately to non-linguistic communicative contexts. These findings have important implications for the development of pragmatic abilities.

KEYWORDS

epistemic, Grice, language acquisition, non-linguistic communication, pragmatics, scalar implicature

1 | INTRODUCTION

Communication depends on the ability to go beyond the literal meaning of what is said and draw inferences about what the speaker intended to convey. If one goes to a zoo, and the zookeeper says, 'Some of the animals are safe to pet', one must be able to interpret this correctly as 'Some and not all of the animals are safe to pet' if one values one's limbs. According to Grice (1975, 1989), adults can compute these non-literal meanings because they assume that conversational partners must work together to further the goals of the conversation (the *Cooperative Principle*). To do so, communicators must obey a set of conversational principles or *maxims*. The above example relies on the maxim of quantity, which states that a speaker in a conversation should give as much information as needed. Given that the statement 'All of the animals are safe to pet' would have given greater relevant information if true (and since the exchange is presumed to be cooperative), the listener infers that the choice of the less-informative statement implies that the zookeeper is not in a position to offer the more-informative statement—either because the zookeeper does not know for a fact that such a statement is true or more likely (given the zookeeper's expertise) because the zookeeper knows that it is *not* true. This inference is known as a *scalar implicature*.

Scalar implicatures rely on a comparison of a lexical item to a stronger alternative that the speaker could have used but did not (Grice, 1989). In the zoo example, the lexical alternatives 'some' and 'all' form a scale ordered in terms of logical strength (Horn, 1972, 1989). 'All of the animals are safe to pet' is the stronger alternative because it entails the weaker alternative 'Some of the animals are safe to pet', but not vice versa. In order to compute an implicature, the listener must be able to access this logically ordered scale (in addition to quantifiers, modals and numerals are other examples of logical scales; Horn, 1989; Levinson, 2000). In other cases, scalar implicatures rely on ad hoc scales that depend upon context-specific information (Hirschberg, 1985). For example, if a tiger, a llama, and a goat are in pens, and a zoo visitor is told, 'The llama and the goat

are safe to pet', the implication arises that the tiger is not safe to pet. Following the previous logic, given that the statement 'The tiger, the llama, and the goat are safe to pet' would have given greater relevant information if true, the listener infers through the choice of the less-informative statement that the tiger is not safe to pet.

Adults successfully derive scalar implicatures, although it has been argued that scalar implicature derivation requires cognitive processing resources (de Neys & Schaeken, 2007; Marty, Chemla, & Spector, 2013) and might involve lengthier processing time compared with literal sentences (Huang & Snedeker, 2009a; although see Grodner, Klein, Carbary, & Tanenhaus, 2010; Foppolo & Marelli, 2017; cd. also Degen & Tanenhaus, 2015). Children, however, often struggle to grasp the subtleties of these hidden intended meanings (Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Foppolo, Guasti, & Chierchia, 2012; Guasti et al., 2005; Huang & Snedeker, 2009b; Noveck, 2001; Papafragou & Musolino, 2003; among others): For instance, 5-year-olds—unlike adults—judge that the sentence 'Some of the horses jumped over the fence' is a good description of an event in which *all* of the horses jumped over the fence, even though the sentence is underinformative (Papafragou & Musolino, 2003). Children's performance improves in paradigms in which they are given more nuanced response choices beyond a binary judgement (Katsos & Bishop, 2011), when relevant scalar alternatives are made more easily accessible (Barner, Brooks, & Bale, 2011; Skordos & Papafragou, 2016; Stiller, Goodman, & Frank, 2015), or when task demands are simplified (Pouscoulous, Noveck, Politzer, & Bastide, 2007).

An open issue in the field is the extent to which children are able to both appraise and sensitively adapt to information about the speaker during scalar pragmatic reasoning. Under broadly Gricean accounts, the hearer needs to engage in a rich computational process that takes into account the speaker's communicative intentions given his/her goals and knowledge state (see, e.g., Carston, 1998; Geurts, 2010; Horn, 1972; Sauerland, 2004, 2012; Sperber & Wilson, 1986; see also Chierchia, 2006; Chierchia, Fox, & Spector, 2012 for alternative accounts). Accordingly, Gricean approaches predict that hearers filter the interpretation of scalar terms through the speaker's perspective: The use of a weaker scalar term such as *some* may lead to the inference that the speaker lacks stronger knowledge or (if the speaker is an expert, as in the earlier zookeeper example), the inference that the stronger term does not hold, as far as the speaker knows (Geurts, 2010; Sauerland, 2004). Evidence from both eye tracking (Breheny, Ferguson, & Katsos, 2013) and reading times (Bergen & Grodner, 2012) during online comprehension suggests that adults take into account speaker knowledge during the derivation of scalar implicatures. In a recent demonstration, adult comprehenders judged underinformative sentences more leniently when the sentences belonged to non-native compared with native speakers, presumably because non-native speakers know less about the lexical resources in a language (Fairchild & Papafragou, 2018). For children, however, sensitivity to speaker knowledge is still an unsettled topic.

Available experimental evidence suggests that children are not able to incorporate information about a speaker's epistemic state into the derivation of scalar implicatures before the age of five, and even then, performance is highly fragile (Barner, Hochstein, Rubenson, & Bale, 2018; Hochstein, Bale, Fox, & Barner, 2016; Papafragou, Friedberg, & Cohen, 2018). In a study by Papafragou et al. (2018), children were presented with videos of two observers, one with full knowledge of an event that occurred (e.g., a girl coloring a star) and one who fell asleep part way through. They then heard either a more-informative or a less-informative statement describing the event (e.g., 'The girl colored some/all of the star') and had to attribute the statement to either the limited-knowledge or the full-knowledge observer. According to the maxim of quantity, only a knowledgeable observer had sufficient evidence to assert the more-informative statement, and only a speaker who lacked knowledge was justified in uttering a less-informative statement. Both 4- and 5-year-olds succeeded with more-informative statements, but only 5-year-olds performed above chance on less-informative statements (and even then, accuracy hovered around 60%). These results persisted when the quantifiers were replaced with ad hoc scales. In a later manipulation which removed the epistemic component, 4-year-olds' performance improved. Similarly, in two recent studies (Barner et al., 2018; Hochstein et al., 2016), children were presented with two action figures, one blindfolded and one with full visual access. The action figures watched as an animal stole an object and announced 'Look, an orange and a banana! Look what I'm taking!' and were asked what happened. Barner et al. (2018) found that 4-year-old children presented with disjunctive sentences (e.g., 'He took an orange or a banana') failed to compute non-scalar 'ignorance' implicatures (i.e., they failed to match the disjunctive statement to the blindfolded speaker and thus to reason that only a speaker who lacks knowledge is pragmatically justified in producing a disjunctive statement), despite succeeding in a matched ad hoc implicature task in which the epistemic aspect was removed. Barner et al. (2018) concluded that 4-year-olds have substantial difficulty with the epistemic aspects of implicature derivation and even potentially compute scalar implicatures in the absence of epistemic reasoning (cf. Hochstein, Bale, & Barner, 2018).

However, there may be another explanation for these failures. In the studies just reviewed, children had to watch lengthy scenarios while tracking the epistemic state of multiple speakers and the actions ofmultipleagents. These high task-specific cognitive processing

Research highlights

- Human communication relies on the ability to consult the speaker's mental state to infer meaning in context.
- Four- and 5-year-olds adapt to a speaker's epistemic state during the derivation of scalar inferences.
- This ability does not generalize immediately to non-linguistic communicative contexts.
- These findings show early sophisticated computation of pragmatic inferences in young children.

demands may have masked 4-year-olds' ability to incorporate epistemic state into scalar implicature derivation (see Papafragou et al., 2018 for discussion of this possibility, also Pouscoulous et al., 2007). Additionally, Barner et al. (2018) argument that 4-year-olds compute scalar implicatures in the absence of epistemic reasoning hinges on the assumption that the ignorance implicature task in which children fail is minimally different (and only in terms of epistemic computations) from the ad hoc scalar implicature task that children pass. However, the differences may not be minimal; children have been shown to struggle with disjunction (Singh, Wexler, Astle-Rahim, Kamawar, & Fox, 2016; although see Tieu, Romoli, Zhou, & Crain, 2015), and it may not be clear to children that the ignorant speaker (who is blindfolded) would have enough information to produce even a disjunctive statement ('He took a carrot or a banana'). Thus, the question of whether children can incorporate speaker perspective into scalar implicature derivation needs to be examined further.

Children's sensitivity to speaker knowledge during pragmatic comprehension bears on broader debates over the extent to which children are able to flexibly adapt to the perspective of a communicative partner, with some commentators claiming that children remain egocentric and inflexible until late in development (Davies & Katsos, 2010; Epley, Morewedge, & Keysar, 2004; Girbau, 2001; Perner & Leekam, 1986; Piaget, 1970; Shatz, 1980), and others arguing that children display sophisticated adaptations to others at early ages (Bahtiyar & Küntay, 2009; Matthews, Lieven, Theakston, & Tomasello, 2006; Nadig & Sedivy, 2002; O'Neill, 1996; see Grigoroglou & Papafragou, 2018, 2019, for a review). Similarly, some researchers have argued that children rely on social reasoning of a Gricean character in word learning (Akhtar, Carpenter, & Tomasello, 1996; Baldwin, 1993a, 1993b; Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Clark, 1990; Diesendruck, Markson, Akhtar, & Reudor, 2004; Southgate, Chevallier, & Csibra, 2010), while others have challenged the proposal that word learning requires Gricean reasoning (de Marchena, Eigsti, Worek, Ono, & Snedeker, 2011; Preissler & Carey, 2005; Regier, 2005).

Here, across three experiments, we asked whether 4- and 5-year-olds are able to assess and sensitively adapt to a speaker's knowledge state during pragmatic reasoning using a novel task. Our task, inspired by paradigms developed to study reference and other communicative phenomena in the visual world (e.g., Nadig & Sedivy, 2002), was designed to simplify the cognitive demands of previous tasks: It established the speaker's knowledge state through visual access to a simple, static display as opposed to a complex, dynamic event, and provided a clear conversational goal. Children were presented with either a more-informative or a less-informative statement about the contents of a box. The statements formed an ad hoc scale ordered in terms of logical strength: The more-informative statement (stronger alternative) mentioned both of the objects in a box, while the less-informative statement (weaker alternative) mentioned only one of them, and children had to decide which one of two possible boxes a speaker was describing. The speaker had complete visual access to the contents of one box (and hence complete knowledge) but only partial visual access to the contents of the second box (hence partial knowledge); crucially, the boxes did not differ from the participant's perspective. We expected, following the logic of Papafragou et al. (2018), that, if children and adults derive pragmatic inferences using a Gricean approach, they should use epistemic reasoning to link the more-informative statement to the speaker under conditions of complete knowledge and the less-informative statement to the speaker under conditions of partial knowledge. If children are inflexible or insensitive to the speaker's perspective, they would be expected to choose between the boxes at chance or rely on other potential biases (perhaps a preference for the fully knowledgeable speaker; see, e.g., Hochstein et al., 2016; Ozturk & Papafragou, 2016). Evidence that young children and adults could both assess a speaker's epistemic state and use that assessment to interpret scalar statements would support a mentalistic model of implicature computation and contribute to the broader conclusion that children incorporate the speaker's perspective when interpreting utterances in context.

In Experiment 1, we used this paradigm to ask whether 4- and 5-year-old children consult a speaker's epistemic state in interpreting scalar statements. In Experiment 2, we extended this method to explore how explicit presentation of alternatives impacts the youngest children in our sample. Finally, in Experiment 3, we adapted this paradigm into a non-linguistic task to probe the mechanisms underlying epistemic pragmatic inference in children.

2 | EXPERIMENT 1

2.1 | Methods

2.1.1 | Participants

Twenty-six 4-year-olds (M_{age} = 4;6, *range*: 4;0–4;11, and 13 female) and twenty-six 5-year-olds (M_{age} = 5;5, *range*: 5;0–5;11, and 17 female) participated. Children were recruited from Newark (DE) preschools and the Delaware Children's Museum in Wilmington, DE. An additional ten children contributed data but were excluded for failing preliminary tests (see Procedure for criteria). A control group of twenty-six adult participants was also tested. Adult participants were recruited with a HIT (human intelligence task) posting on MTurk. No age or gender data were collected for this sample.

2.1.2 | Procedure

For child participants, the experiment began with an introductory phase designed to familiarize them with the types of displays used in the main task. Participants were first presented with a single photograph on a computer screen (Figure 1, panel 1). The photograph depicted a girl sitting across from and facing out toward the participant. In front of her was a cardboard box with two vertical compartments. The compartment to the left (from the participant's viewpoint) was see through and empty. The compartment to the right contained an

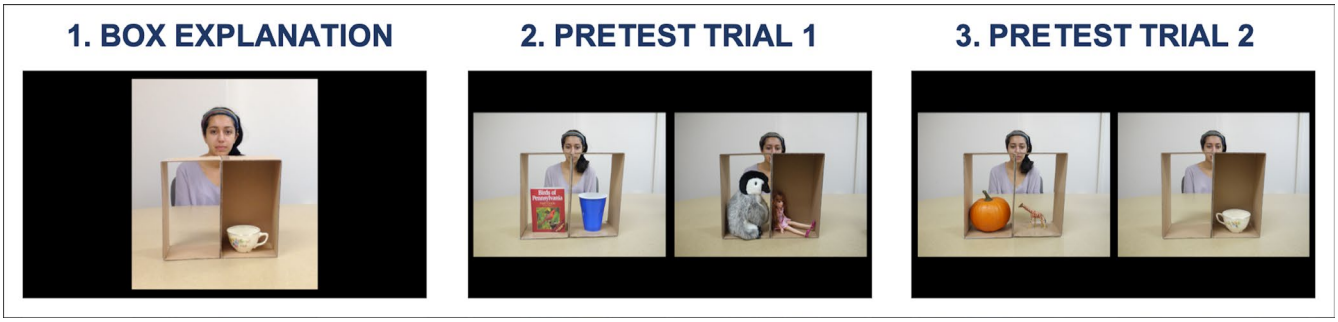

FIGURE 1 Visual displays for the introductory phase of Experiment 1

object (a teacup) but was blocked so that only the participant but not the girl could see its contents.

The children were told that the girl in the photograph was the experimenter's friend Danielle, and she had a special box in front of her. The children were then asked whether they themselves could look through the two parts of the box ('Can you look through this side?'), and if not, why not. (For the blocked compartment, the children typically said no and mentioned that it was closed or blocked.) Children were asked whether they thought Danielle could look through the blocked side ('So do you think she can look through that one?' <pointing>). The children were then asked whether Danielle knew about the item in the blocked compartment ('Does she know there's a teacup there?'). No feedback was given, but the response was recorded and used for exclusions, as will be explained later.

All participants then completed two pretest trials (Figure 1, panels 2 and 3). In each trial, two photographs were shown side by side. One photograph showed Danielle and a limited-access box similar to the introduction phase; the other showed Danielle and a full-access box where both compartments were unobstructed. One photograph appeared on screen, followed by the other one after 2 s, as the experimenter explained the task (presentation order/side of the screen for the limited-access box photograph was counterbalanced across participants). Participants were told that they were going to play a game with the boxes. The experimenter explained that Danielle would look at each box and, pointing to each side of the boxes, reminded children whether it was open so that Danielle could look through it or closed so that she could not. Participants were told that Danielle was going to talk about just one of the boxes, and they had to decide which box she was talking about. After this explanation ended (and both photographs had stayed up for 2 s), children heard a recorded sentence from a female speaker and were asked, 'Which box is she talking about?' Both photographs remained on screen until children responded. The two boxes had different contents, so the sentence unambiguously described one of them. For instance, in pretest trial 1, the full-access box had a book and a cup, the limited-access box had a penguin and a doll, and the sentence was 'I see a book and a cup'. In pretest trial 2, the full-access box had two objects, but the limited-access box only had an object in the blocked compartment, and nothing in the open compartment. The sentence was as follows: 'I see nothing'. One 4-year-old and two 5-year-olds failed both pretest trials and were excluded.

Participants then completed 8 test trials. The setup was the same as the pretest trials. However, the contents of the boxes within a trial were identical (e.g., a spoon and a bowl; Figure 2), and only one of the objects in the limited-access box was visible to the experimenter's friend (here, the spoon). There were two within-subject conditions (More-Informative, Less-Informative) depending on whether children heard a more-informative statement mentioning both objects (e.g., 'I see a spoon and a bowl') or a less-informative statement mentioning only one object—the one that remained visible to the speaker in the limited-access box but was actually present in the other box too (e.g., 'I see a spoon'). Participants were again asked, 'Which box is she talking about?'

For test trials 1–4, the girl in the photographs was Danielle; for trials 5–8, the girl in the photographs was Julia, another friend of the experimenter's that was introduced for variety (the prerecorded statements had a different female voice for Julia). Participants were given 4 more-informative and 4 less-informative test sentences in a mixed order, always beginning with a more-informative one. This trial order was chosen given previous evidence that children benefit from trial orders which present stronger (more-informative) relevant alternatives first (Skordos & Papafragou, 2016; see also Barner et al., 2011; Stiller et al., 2015). Two presentation lists were created; assignment of statements corresponding to each condition (More-Informative, Less-Informative) to trials was counterbalanced across lists. The position of the limited-access box photograph across trials was also counterbalanced within each list. Statements had neutral stress (i.e., 'I see a spoon' and not 'I see a SPOON').

To introduce Julia and to remind children of the critical properties of the boxes, after the first 4 test trials, children were presented with a reminder trial and questions modeled after the initial box introduction phase. The trial included a photograph of a new friend, Julia, and a limited-access box with only one object (a blue plastic cup in the blocked compartment). As in the box introduction phase, children were asked whether they could look through each side of the limited-access box and whether Julia could look through the blocked side (for the importance of such reminders of the visual properties of the display, see Nadig & Sedivy, 2002). No feedback was given. We also asked whether Julia knew about the contents of the blocked compartment ('Does she know there's a cup there?'). Children who replied 'yes' to this question in both the box introduction and this reminder phase were excluded on the basis that

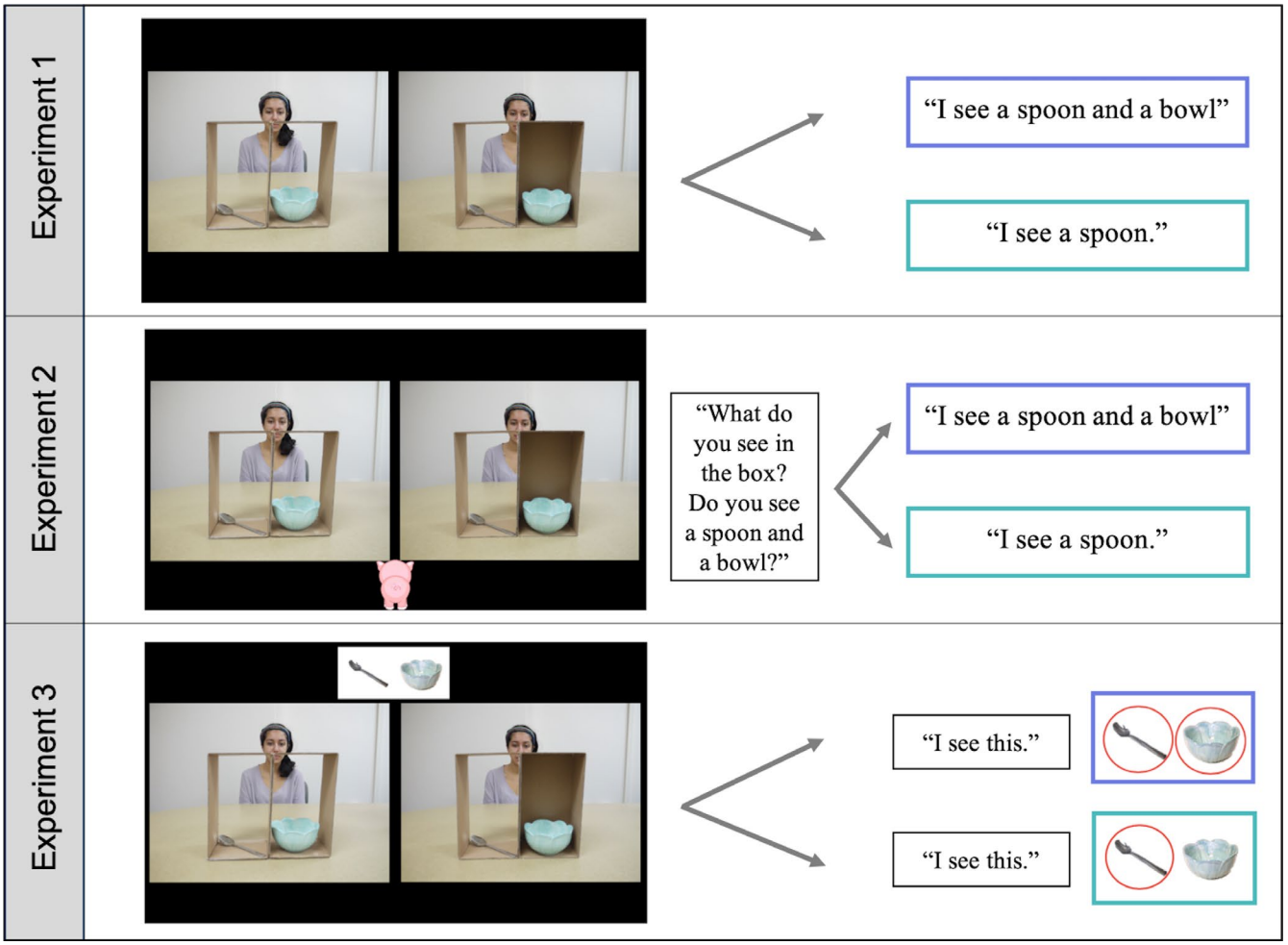

FIGURE 2 A schematic view of the visual and verbal stimuli for a test trial in Experiments 1, 2, and 3. Across all studies, the photograph on the left depicts the 'full-access' box (and the full-knowledge person). The photograph on the right depicts the 'limited-access box' (and the limited-knowledge person). In the More-Informative condition, participants heard a statement mentioning two objects (Experiments 1 and 2) or saw the action of circling two objects (Experiment 3) and were expected to select the full-access box. In the Less-Informative Condition, participants heard a statement mentioning one object (Experiments 1 and 2) or saw the action of circling one object (Experiment 3), and were expected to select the limited-access box

they did not understand the nature of the limited-access box (N = 6 4-year-olds, 1 5-year-old).

2.1.3 | Predictions

Two patterns should emerge if participants could successfully incorporate the perspective and knowledge of the speaker into their responses on test trials, in line with a Gricean model of pragmatic inference. In the More-Informative condition, they should take the statement (e.g., 'I see a spoon and a bowl') to describe the full-access box (and thus belong to the fully knowledgeable speaker), because the girl could not see the bowl in the limited-access box. In the Less-Informative condition, they should take the statement (e.g., 'I see a spoon') to describe the limited-access box (and thus belong to the limited-knowledge speaker) because it would be underinformative under these circumstances for the full-knowledge speaker to only mention one object instead of both. Notice that these responses on both conditions presuppose sensitivity to speaker knowledge since from the participant's perspective both boxes have identical, visible contents. If children failed to consider the speaker's perspective, they were expected to respond at chance or rely on other potential biases (e.g., a preference for knowledgeable speakers; see also Hochstein et al., 2016; Ozturk & Papafragou, 2016).

2.2 | Coding

Correct responses involved selecting the full-access box in the More-Informative condition and the limited-access box in the Less-Informative condition. Participants were given a mean accuracy score between 0 and 1 for each condition. In the critical Less-Informative

condition, most participants (72 out of 78; 92.3%) had scores of either 0 or 1, and an additional 4 (5.1%; combined 97.4%) had scores of either 0.25 or 0.75. Thus, for each condition, participants with a mean score equal to or greater than 0.75 were designated as passers and those with a mean score equal to or lower than 0.25 as failers. Any participant with a score of 0.50 was also designated as a failer, even though this response type was vanishingly low across all studies.

2.3 | Results

A logistic mixed effects model with condition (More-Informative and Less-Informative) and age (4, 5, adult) as fixed variables and with subject and item as random factors could not converge because of the almost total lack of variance in the data (Eager & Roy, 2017). Non-parametric tests were thus conducted on the data.

Adults and 5-year-olds performed at ceiling in this task (see Table 1). Fisher's exact test revealed no significant differences in performance between adults and 5-year-olds in either condition. Even in 4-year-olds, an exact test of goodness of fit showed that the number of passers in both the More-Informative and the Less-Informative condition was significantly different from the expected ratio due to chance (More-Informative: $p = .002$, Less-Informative: $p = .029$). Furthermore, Fisher's exact test revealed no significant differences between 4-year-olds and either adults or 5-year-olds in the More-Informative condition ($p = 1$ for all comparisons; Bonferroni correction). The same test did indicate a significant difference between 4-year-olds and adults ($p = .01$) and a marginally significant difference between 4-year-olds and 5-year-olds ($p = .05$) in the Less-Informative condition. For 4-year-olds, performance on the More-Informative condition was marginally better compared with the Less-Informative condition (Fisher's exact test, $p = .05$, 2-tailed).

TABLE 1 Number of passers and failers in the more-informative and less-informative conditions for Experiment 1 for adults, 5-year-olds, and 4-year-olds

		Condition	
	Classification	More-informative	Less-informative
Adults	Passers	26***	26***
	Failers	0	0
5-year-olds	Passers	26***	25***
	Failers	0	1
4-year-olds	Passers	25***	19*
	Failers	1	7

Note: Asterisks denote performance significantly different from the expected ratio of passers/failers due to chance.

*$p < .05$.

**$p < .01$.

***$p < .001$.

2.4 | Discussion

Experiment 1 investigated whether 4- and 5-year-old children are able to incorporate epistemic reasoning into the derivation of scalar inferences. Results suggest that children are capable of this type of complex pragmatic reasoning; in a simple task using a novel paradigm inspired by referential communication tasks in the visual world, both 4- and 5-year-olds were able to successfully interpret statements of different informational strength in accordance with the knowledge state of the speaker. In fact, 5-year-olds performed at an adult-like level in this new task. The findings of the present study lower prior estimates of the age at which children display the ability to take the epistemic step during scalar inference derivation (Hochstein et al., 2016; Papafragou et al., 2018)—and are consistent with other studies with very simple paradigms that show an ability to compute scalar inferences (without special attention to the epistemic component) at young ages (Stiller et al., 2015).

The present data raise two possible issues. First, there are different varieties of scalar implicature depending on the specificity of the alternative that is being negated (see Geurts, 2010). For example, a statement such as 'I see a spoon' could be interpreted to mean either 'I see a spoon and nothing else' or 'I see a spoon and not a bowl', depending on whether the speaker had access to the more-informative alternative (among other possible factors). In our task, the limited-knowledge speaker did not know the context-specific more-informative alternative (although the child did), and thus, the less-informative statement could only be interpreted as conveying a 'nothing else' implicature (see the adult data in Breheny et al., 2013 for this type of inference). However, in most prior developmental studies where 4-year-old children derived ad hoc scalar implicatures successfully (Barner et al., 2011, 2018; Papafragou & Tantalou, 2004), the speaker had full access to the contextual set of alternatives and thus the more-informative alternative could be taken to be negated. It would be valuable to setup a context with explicitly presented contextual alternatives to better compare 4-year-olds' inferences to previous tasks. Second, while adults and 5-year-olds performed at ceiling, 4-year-olds did not; the majority displayed very successful pragmatic inference, but some 4-year-olds relied on some other strategy (e.g., choosing the full-knowledge speaker for all trials). Further examination of performance within this age group could provide a clearer picture of pragmatic development. In Experiment 2, we addressed both of these issues.

3 | EXPERIMENT 2

In Experiment 2, we replicated Experiment 1 but introduced a conversational context such that the test sentences ('I see a spoon and a bowl', 'I see a spoon') were now the response to a question from a conversational partner ('What do you see in the box? Do you see a spoon and a bowl?'). By providing a response to an overt question under discussion (QUD; see Roberts, 1996, 2004; cf. Stalnaker,

1979) that explicitly invoked the stronger alternative, we increased the likelihood that the speaker would be taken to negate a specific stronger alternative (i.e., 'I see a spoon and not a bowl'). Furthermore, we focused exclusively on 4-year-old participants and divided them into younger and older subgroups to gain a clearer picture of scalar implicature development at this age.

3.1 | Methods

3.1.1 | Participants

Forty 4-year-olds contributed data; they were divided into a younger group (N = 20, M_{age} = 4;3, *range*: 4;0–4:5, 13 female) and an older group (N = 20, M_{age} = 4;9, *range*: 4;6–4:11, 15 female). Children were recruited from Newark (DE) preschools and the Delaware Children's Museum in Wilmington, DE. An additional six children participated but were excluded from data analyses for failing to meet inclusionary criteria (see Procedure). A control group of twenty adult participants (M_{age} = 29.1, *range*: 22–35, 12 female) was also tested. Adult participants were recruited with a HIT (human intelligence task) posting on MTurk.

3.1.2 | Procedure

Experiment 2 used the same stimuli and basic procedure as Experiment 1 but with the addition of a new character (as well as some smaller changes detailed below). As before, during the box introduction phase, participants were familiarized with the limited-access box and were told that they would play a game with boxes. For the pretest trials, they were shown two photographs with Danielle and the limited-access versus full-access box. They were told that Danielle would look at both boxes, 'pick' one of them, and they would have to 'figure out which box she picked.' At that point, the experimenter said, 'Let's see if someone can help us!' A small clipart pig appeared below the photographs in the middle of the screen. The experimenter greeted the character ('Hello, Wilbur!') and Wilbur (through a prerecorded message) responded 'Hello'. The experimenter then asked: 'Wilbur, can you ask Danielle some questions to help us figure out which box she picked?' Wilbur agreed, then turned to face the pictures, as if talking to Danielle, and asked her, 'Danielle, what do you see in the box? Do you see an X [name of object]?' followed by Danielle's response. Participants were asked, 'Which box did she pick?' and had to point at a box.

For test trials, the procedure was the same, but Wilbur's question always mentioned two objects (e.g., for the trial in Figure 2: 'Danielle, what do you see in the box? Do you see a spoon and a bowl?'). The original sentences from Experiment 1 with less-informative and more-informative test sentences (uttered in 'Danielle's' and 'Julia's' voices) were used.

The pretest trials differed slightly from Experiment 1. As before, the girl's responses unambiguously described one of the boxes. However, unlike Experiment 1, there was only one object in each box (not two), always appearing in the open compartment. In pretest trial 1, the full-access box had a spoon, the limited-access box had a penguin, and the exchange was as follows: 'Danielle, what do you see in the box? Do you see a penguin?'—'I see a penguin'. In pretest trial 2, the full-access box had a book, the limited-access box had a box, and the exchange was as follows: 'Danielle, what do you see in the box? Do you see a basket?'—'I see a book'. The structure of these pretest trials, and Wilbur's incorrect guess in pretest trial 2, was setup to prevent participants from associating an answer that matched or mismatched the wording of the question with a specific box. Given that in the test trials, participants should select the *full-access box* when the answer matched the question (e.g., '…Do you see a spoon and a bowl?' 'I see a spoon and a bowl'), and in pretest trial 1, the correct answer was to select the *limited-access box* when the answer matched the question. Inversely, given that in test trials, participants should select the *limited-access box* when the answer mismatched the question (e.g., '…Do you see a spoon and a bowl?' 'I see a spoon'), and in pretest trial 2, the correct answer was to select the *full-access box* when the answer mismatched the question. Participants were excluded for failing the pretest trials (N = 1 younger 4-year-old) or not completing the task (N = 1 younger 4-year-old).

We also made a slight change in the exclusion criteria in Experiment 2. The children who incorrectly replied during the box introduction phase that the girl knew the identity of the object in the blocked compartment were now given corrective feedback ('No, I don't think she knows there's a teacup there because she can't look through that side; it's blocked') and were only excluded if they replied incorrectly again at the reminder trial midway through the test phase (N = 4 younger 4-year-olds). The majority of 4-year-olds (38 out of 46) understood the perspective and knowledge requirements of the box in the photograph without needing feedback.

3.2 | Coding

Again, the majority of participants (49 out of 60; 82%) had scores of either 0 or 1 in the critical Less-Informative condition, and an additional 9 (15%; combined 97%) had a score of 0.75, so coding was kept identical to Experiment 1.

3.3 | Results

Adults and both groups of 4-year-olds performed well in both the More-Informative and Less-Informative conditions (see Table 2). Fisher's exact test comparisons did not reveal any significant differences on individual conditions between adults and older 4-year-olds (More-Informative: p = 1, Less-Informative: p = .49) or adults and younger 4-year-olds (More-Informative: p = .60, Less-Informative: p = .23). Additionally, there were no significant differences between the two subgroups of 4-year-olds per condition (More-Informative: p = .61, Less-Informative: p = .41). Further analyses (exact test of goodness of fit) revealed that the number of passers per condition

TABLE 2 Number of passers and failers in the more-informative and less-informative conditions for Experiment 2 for adults, older 4-year-olds (4;6–4;11), and younger 4-year-olds (4;0–4;5)

		Condition	
	Classification	More-informative	Less-informative
Adults	Passers	20***	20***
	Failers	0	0
Older 4s	Passers	19***	18***
	Failers	1	2
Younger 4s	Passers	17**	15*
	Failers	3	5

Note: Asterisks denote performance significantly different from the expected ratio of passers/failers due to chance.

*$p < .05$.

**$p < .01$.

***$p < .001$.

was significantly different from the expected ratio due to chance for all age groups (adults and older 4s: $p < .001$ for all comparisons; younger 4s: More-Informative: $p = .002$, Less-Informative: $p = .041$). Finally, Fisher's exact test showed that performance did not differ between the More-Informative and Less-Informative conditions for either the older ($p = 1$) or the younger 4-year-olds ($p = .70$).

3.4 | Discussion

Experiment 2 replicated the finding of Experiment 1:4-year-olds can incorporate speaker knowledge state into the derivation of scalar inferences. By recruiting greater numbers within this age group, we could see that even young 4-year-olds successfully use pragmatic principles to attribute statements of varying logical strength to speakers in accordance with their knowledge state. These results suggest that preschool children are able to derive scalar inferences with epistemic sensitivity both in cases where the speaker's statement ('I see a spoon') is taken as negating a specific stronger alternative ('I see a spoon and not a bowl'; Experiment 2), and in cases where the speaker's statement is taken as conveying a 'nothing else' implicature ('I see a spoon and nothing else'; Experiment 1).

Could young children be relying on other strategies to succeed in Experiments 1 and 2 instead of computing genuine scalar inferences? One possibility could be that children used a superficial mapping strategy to succeed: Given children's strong performance in the More-Informative condition, they could have correctly reasoned about the full-access box for the More-Informative trials and then just selected the other option for the Less-Informative trials. Another possibility is that children could select the correct boxes in the Less-Informative condition on the basis of probability: There is a higher probability that the speaker who sees only one object will mention that object compared to the other speaker. We believe that these possibilities are unlikely explanations for our findings, and we return to them in the discussion of Experiment 3.

4 | EXPERIMENT 3

In Experiments 1 and 2, we found robust evidence that 4-year-olds are able to adapt to speaker knowledge during pragmatic inference. This raises questions about whether this ability extends to other forms of pragmatic inference. Grice (1989) proposed that pragmatic principles, including the maxim of quantity, extend to other types of cooperative communication (see also Sperber & Wilson, 1986), but relevant evidence so far in children and adults is limited (Bass, Bonawitz, & Gweon, 2017; Gweon & Asaba, 2018; Papafragou et al., 2018). In a previous study, 4-year-old children failed to incorporate speaker knowledge during scalar inference in a non-linguistic paradigm adapted from a linguistic paradigm; however, they also failed in the linguistic version (Papafragou et al., 2018). In Experiment 3, we revisit the question of whether children (and adults) adapt to speaker knowledge during pragmatic inference in non-linguistic exchanges using a simple task.

Experiment 3 was identical to Experiment 1, but instead of sentences, the speaker indicated which box she had chosen by circling the objects she saw in that box from a selection of pictures. Thus, instead of verbally mentioning either two objects ('I see a spoon and a bowl') or one ('I see a spoon'), she indicated what she saw by circling either two objects (a spoon and a bowl) or one (a spoon) from a display with pictures of possible objects. As in our previous experiments, if children (and adults) incorporated the perspective and knowledge state of the communicator, they should recognize that only the full-knowledge person had sufficient evidence to circle both a spoon and a bowl. Similarly, a pragmatic responder should recognize that only the limited-knowledge person was justified in circling only a spoon, as the full-knowledge person who saw both should circle both to disambiguate and be informative in accordance with pragmatic principles of communication.

4.1 | Methods

4.1.1 | Participants

Twenty-three 4-year-olds (M_{age} = 4;4, *range*: 4;0–4;11, 15 female) and twenty-three 5-year-olds (M_{age} = 5;4, *range*: 5;0–5;11, 12 female) contributed data. Children were recruited from Newark (DE) preschools and the Delaware Children's Museum in Wilmington, DE. An additional group of 7 children participated but were excluded from data analyses for failing to meet inclusionary criteria (see Procedure). A control group of twenty-three adult participants (M_{age} = 28.7, *range*: 20–34, 10 female) was also tested. Adult participants were recruited with a HIT (human intelligence task) posting on MTurk.

4.1.2 | Procedure

Experiment 3 modified the stimuli and procedure of Experiment 1 as follows. Within each trial, the original pairs of photographs were presented as in Experiment 1. As before, participants were told that they were going to play a game with the boxes where Danielle would look at both boxes and then select one; participants were told that they had to figure out which box she picked. Participants were told that the toys from the boxes would appear on the top of the screen, and Danielle would circle what she sees 'in just one of the boxes'. This was accomplished by presenting pictures of the objects in the boxes at the top of the screen placed against a white background (Figure 2). Participants heard an audio recording of Danielle saying, 'I see this', while a red circle was slowly drawn around one or both of the objects. Participants were asked, 'Which box did she choose?' For the More-Informative test trials, the girl circled both objects in succession. For the Less-Informative test trials, she circled only one (Figure 2).

The pretest trials in Experiment 3 were slightly different from Experiment 1 in order to prevent participants from associating the spatial position (left/right) of the toys on top of the screen with the spatial position of the box photographs. The photographs for pretest trial 1 were similar to Experiment 1; both boxes contained two unique objects. All four objects appeared as images in the white box above the photographs (Figure 3, panels 2 and 3). The objects in the white box for both pretest trials were arranged in a random order to prevent participants from associating the objects on the left of the white box with the photograph on the left. In pretest trial 2, one object (a cup) appeared in both boxes. Although the object appeared in both boxes, there was only one picture of a cup in the white box (to set the precedent for the test trials; see Figure 2).

With the exceptions above, Experiment 3 used the same counterbalancing, trial order, and photographs as Experiment 1. Participants were excluded for not completing the task (N = 2 4-year-olds), for saying 'yes' when asked whether Danielle knows the identity of the object in the blocked compartment during both box introduction and reminder trials (N = 2 4-year-olds, 1 5-year-old), or because of parental interference during the task (N = 1 4-year-old, 1 5-year-old).

4.2 | Coding

A majority of participants (47 out of 69; 68%) performed at ceiling (1) or floor (0) in the Less-Informative trials, and an additional 17 participants (25%; combined total 93%) performed near ceiling (0.75) or floor (0.25). As a result, coding was kept identical to Experiments 1 and 2.

4.3 | Results

Comparisons between age groups using Fisher's exact test did not reveal any significant differences in the More-Informative condition (see Table 3; adults vs. 4s: p = 1, adults vs. 5s: p = .224, 4s vs. 5s: p = .489). In the Less-Informative condition, the same test revealed a significant difference in performance only between adults and 4-year-olds (p = .029); there was no significant difference between adults and 5-year-olds (p = .284) or between 4-year-olds and 5-year-olds (p = .231). Fisher's exact test revealed a significant difference between the Less-Informative and More-Informative condition for 4-year-olds (p < .001) but not for 5-year-olds (p = .135) or adults (p = .235).

Adults performed significantly differently from the expected ratio due to chance for both conditions in analyses using exact goodness of fit (More-Informative: p < .001, Less-Informative: p < .001). However, 5-year-olds and 4-year-olds did so only in the More-Informative condition (5s: More-Informative: p < .001, Less-Informative: p = .093; 4s: More-Informative: p < .001, Less-Informative: p = 1).

Performance on each condition was compared between Experiments 1 and 3 using Fisher's exact test (we collapsed across age groups in children for simplicity). For adults, there was no significant difference (More-Informative: p = 1, Less-Informative: p = .215). For children, performance was significantly better in Experiment 1 compared with Experiment 3 for the Less-Informative condition (p = .006) but was similar across experiments for the More-Informative condition (p = .559).

FIGURE 3 Visual displays for the introductory phase of Experiment 3. At the end of each pretest trial, participants heard 'I see this' as an animation of a red circle appeared around two of the objects in the array above the photographs in succession. In pretest trial 1, the picture of the book was circled first, followed by the giraffe. In pretest trial 2, the picture of the book was circled first, followed by the cup

TABLE 3 Number of passers and failers in the more-informative and less-informative conditions for Experiment 3 for adults, 5-year-olds, and 4-year-olds

		Condition	
	Classification	More-informative	Less-informative
Adults	Passers	23***	21***
	Failers	0	2
5-year-olds	Passers	21***	16
	Failers	2	7
4-year-olds	Passers	23***	11
	Failers	3	12

Note: Asterisks denote performance significantly different from the expected ratio of passers/failers due to chance.

*$p < .05$.

**$p < .01$.

***$p < .001$.

4.4 | Discussion

As predicted by pragmatic theories (cf. Grice, 1989; Sperber & Wilson, 1986), adults in Experiment 3 used epistemic reasoning to compute scalar inferences from non-linguistic (pictorial) stimuli. Children, however, reliably matched a more-informative communicative act (circling two objects) to a speaker with full knowledge, but failed to reliably match a less-informative communicative act (circling one object) to a speaker with limited knowledge. Given children's earlier linguistic success, and the fact that performance on More-Informative trials (that require perspective-taking but not a scalar inference) remained unaffected from Experiment 1, we do not wish to conclude that children cannot apply Gricean epistemic reasoning to non-linguistic stimuli. It seems more likely that features of the task impacted children's performance in the Less-Informative trials in Experiment 3.

One possibility lies with children's developing understanding of symbolic representation (Allen, Bloom, & Hodgson, 2010; DeLoache, 1991, 2000; Uttal, O'Doherty, Newland, Hand, & DeLoache, 2009). Children have been shown to struggle with the idea that symbolic artifacts (such as pictures) have a *dual nature*: They are both physical objects in themselves as well as abstract representations of something else (DeLoache, 2000; Uttal et al., 2009). The high degree of visual interest (color and detail) in the pictorial representation of the circled objects may have impacted children's ability to overcome their physical nature and assess them as abstract representations meant to represent fully the items in the box. This difficulty may have also impacted children's ability to connect the act of circling objects to a speaker's visual access. Alternatively, given that circling may be less familiar as a communicative act, children may have been unwilling to interpret circling one object as excluding another. We are currently pursuing these topics in ongoing work.

Regardless of the specific explanation for children's behavior in Experiment 3, the selective failure of 4- and 5-year-olds in a paradigm with the same features as Experiment 1 makes alternative explanations for success in Experiments 1 and 2 unlikely. Recall that one possibility raised at the end of Experiment 2 was that children might successfully match a more-informative statement to a full-knowledge speaker and then simply select the other box in the Less-Informative condition without full pragmatic understanding. Experiment 3 shows that this strategy does not apply: Even though children quite successfully chose the full-knowledge communicator for More-Informative trials, they did not match the other type of box to the other communicator. A different possibility was that children could select the correct boxes in the Less-Informative condition on the basis of probability. In Experiment 3, even though the speaker who saw only one object had a higher probability of circling the spoon in the Less-Informative trials, children still did not reliably select that answer. We conclude that simple strategies involving contrast or probability are unlikely to explain children's success in the linguistic versions of this task.

5 | GENERAL DISCUSSION

In conversation, listeners typically assume that the speaker is providing as much relevant information as is required by the purpose of the exchange (and no more than the speaker has evidence for; Grice, 1975). Thus, when a speaker offers a less-informative statement ('Some of the animals are safe to pet'), the listener infers that the speaker is not in a position to offer a more-informative statement ('All of the animals are safe to pet')—either because the speaker does not know whether the more-informative statement is true or (in case the speaker is presumed to be knowledgeable on the topic) because the speaker knows that the more-informative statement is false. In a set of three experiments, we investigated whether 4- and 5-year-olds are able to incorporate speaker knowledge into the computation of ad hoc scalar implicatures. In these studies, we defined being able to compute epistemic scalar inferences as being able to link a more-informative statement with a full-knowledge speaker and a less-informative statement with a limited-knowledge speaker.

Our paradigm was based on a simple, clear way of establishing that someone's knowledge differs from the child's; speaker knowledge state was established through visual access and could be determined instantly by looking at a photograph instead of watching a set of videos or a scenario unfold (Barner et al., 2018; Hochstein et al., 2016; Papafragou et al., 2018). Furthermore, the present paradigm included a clear conversational goal (the identification of the box that the speaker is talking about). In both of these respects, the current study was simpler than past attempts to link the informativeness of a sentence to a speaker's mental state (Barner et al., 2018; Hochstein et al., 2016; Papafragou et al., 2018). Our results provide the first evidence that children as young as 4 can flexibly adjust to a speaker's epistemic state during the derivation of scalar implicatures (Experiments 1 and 2). Furthermore, unlike prior studies, 5-year-olds are as good as adults in consulting the speaker's epistemic state (Experiment 1). Our results lower prior estimates of when young children display sophisticated adaptations to others' epistemic states during implicature derivation.

They further suggest that children's failures in previous tasks are better explained by task-specific processing difficulties rather than insufficient development of epistemic reasoning ability.

From a more general perspective, the present data offer one of the earliest demonstrations of children's success with scalar implicature (cf. also Barner et al., 2011; Stiller et al., 2015; Papafragou et al., 2018, Exp. 2, none of which included an epistemic component). Recall that this area has attracted a lot of experimental attention and is typically thought to pose challenges to 5-year-olds and sometimes even older learners (Chierchia et al., 2001; Guasti et al., 2005; Horowitz, Schneider, & Frank, 2018; Huang & Snedeker, 2009b; Noveck, 2001; Papafragou & Musolino, 2003). Our findings confirm the conclusion that the ability to compute scalar implicatures is fairly task-dependent (Barner et al., 2011; Foppolo et al., 2012; Guasti et al., 2005; Papafragou & Musolino, 2003; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007; Skordos & Papafragou, 2016). Furthermore, they leave open the possibility that a version of the present paradigm could be used to uncover sensitivity to speaker knowledge during scalar implicatures in even younger children.

Viewed most broadly, our results are consistent with studies reporting that sensitivity to others' mental states appears even in infancy (Baldwin, 1991; Kovács, Téglás, & Endress, 2010; Liszkowski, Carpenter, & Tomasello, 2008; Onishi & Baillargeon, 2005; Southgate et al., 2010) and characterizes both speech production and comprehension at early ages (Baldwin, 1993a, 1993b; Carpenter et al., 1998; Clark, 1990; Matthews et al., 2006; Nadig & Sedivy, 2002; O'Neill, 1996; Shatz & Gelman, 1973; Southgate et al., 2010). From a theoretical perspective, our results comport with—and offer support to—broader pragmatic theories according to which scalar implicature derivation (alongside other pragmatic phenomena) requires rich computations about the speaker's perspective and knowledge state (Carston, 1998; Geurts, 2010; Horn, 1972; Sauerland, 2004, 2012; Sperber & Wilson, 1986). Furthermore, they offer grounds for assuming continuity between the mechanisms responsible for the computations of these inferences in adults (see Bergen & Grodner, 2012; Breheny et al., 2013; cf. Fairchild & Papafragou, 2018) and young learners.

The findings and paradigm from this set of experiments provide fertile ground for a continued investigation into the pragmatic ability of young children. Notice that in the present set of studies children's scalar inference computation was highly supported by design factors such as providing relevant alternatives, selecting between two photographs in a forced-choice paradigm, etc. A promising direction for future research would involve manipulating or reducing this support to better identify which factors make the greatest contribution to children's success.

A second direction for future work concerns the extension of pragmatic principles to non-linguistic communication. Our results show that, as predicted by Gricean and later accounts (Grice, 1975; Sperber & Wilson, 1986), adults generalize pragmatic principles to other forms of purposive exchanges, for instance, by applying the maxim of quantity to pictorial symbols (Experiment 3). However, children do not immediately do the same, perhaps because of the features of our non-linguistic task. It remains to be seen whether different instances of ostensive communication could reveal children's ability to reason about what is contained versus omitted in pictures to infer what the creator of the picture wanted to convey, as predicted by pragmatic accounts.

Finally, the current paradigm could be adapted to test whether children are sensitive to calculations involving epistemic state in pragmatic domains beyond implicature. For instance, methods similar to the present ones could be extended to the domain of word learning or referential communication to adjudicate between differing accounts over whether children engage in rich, Gricean pragmatic reasoning during these processes (Clark, 1990; Diesendruck & Markson, 2001; Matthews et al., 2006; Nadig & Sedivy, 2002; O'Neill, 1996) or not (Conti & Camras, 1984; de Marchena et al., 2011; Glucksberg, Krauss, & Higgins, 1975; Preissler & Carey, 2005). Ultimately, the current results and methods should be integrated within a unified account of how children use social-pragmatic reasoning to interpret a variety of linguistic expressions (and also non-linguistic communicative symbols) in accordance with broad principles of communication.

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CONFLICT OF INTEREST

The authors of this paper have no conflicts of interest to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Akhtar, N., Carpenter, M., & Tomasello, M. (1996). The role of discourse novelty in early word learning. *Child Development*, *67*(2), 635–645. https://doi.org/10.2307/1131837

Allen, M. L., Bloom, P., & Hodgson, E. (2010). Do young children know what makes a picture useful to other people? *Journal of Cognition and Culture*, *10*, 27–37. https://doi.org/10.1163/156853710x497158

Bahtiyar, S., & Küntay, A. C. (2009). Integration of communicative partner's visual perspective in patterns of referential requests. *Journal of Child Language*, *36*(3), 529–555. https://doi.org/10.1017/s0305000908009094

Baldwin, D.A. (1991). Infants' contribution to the achievement of joint reference. *Child development*, *62*(5), 875–890.

Baldwin, D. A. (1993a). Infants' ability to consult the speaker for clues to word reference. *Journal of Child Language*, *20*(2), 395–418. https://doi.org/10.1017/s0305000900008345

Baldwin, D. A. (1993b). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology*, *29*(5), 832. https://doi.org/10.1037/0012-1649.29.5.832

Barner, D., Brooks, N., & Bale, A. (2011). Accessing the unsaid: The role of scalar alternatives in children's pragmatic inference. *Cognition*, *188*, 87–96. https://doi.org/10.31234/osf.io/jufdb

Barner, D., Hochstein, L. K., Rubenson, M. P., & Bale, A. (2018). In K. Syrett & A. Arunachalam (Eds.), *Semantics in Acquisition*. *Amsterdam: Benjamins* (pp. 326–349). https://doi.org/10.1075/tilar.24.14bar

Bass, L., Bonawitz, E., & Gweon, H. (2017). Didn't know, or didn't show? Preschoolers consider epistemic state and degree of omission when evaluating teachers. In G. Gunzelmann, A. Howes, T. Tenbrink, & E. J. Davelaar (Eds.), *Proceedings from the 39th Meeting of the Cognitive Science Society* (pp. 105–110). Austin, TX: Cognitive Science Society.

Bergen, L., & Grodner, D. J. (2012). Speaker knowledge influences the comprehension of pragmatic inferences. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *38*, 1450. https://doi.org/10.1037/a0027850

Breheny, R., Ferguson, H., & Katsos, N. (2013). Taking the epistemic step: Toward a model of on-line access to conversational implicatures. *Cognition*, *126*, 423–440. https://doi.org/10.1016/j.cognition.2012.11.012

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *i–vi*, 1–143. https://doi.org/10.2307/1166214

Carston, R. (1998). Negation, 'presupposition' and the semantics/pragmatics distinction. *Journal of Linguistics*, *34*(2), 309–350. https://doi.org/10.1017/s0022226798007063

Chierchia, G. (2006). Broaden your views: Implicatures of domain widening and the "logicality" of language. *Linguistic Inquiry*, *37*(4), 535–590. https://doi.org/10.1162/ling.2006.37.4.535

Chierchia, G., Crain, S., Guasti, M. T., Gualmini, A., Meroni, L. (2001). The acquisition of disjunction: Evidence for a grammatical view of scalar implicatures. In A.-H.-J. Do (Ed.), *BUCLD 25 proceedings* (pp. 157–168). Somerville, MA: Cascadilla Press.

Chierchia, G., Fox, D., & Spector, B. (2012). Scalar implicature as a grammatical phenomenon. In C. Maienborn, K. von Heusinger & P. Portner (Eds.), *Semantics: An international handbook of natural language meaning* (Vol. *III*, pp. 2297–2331). Berlin: Mouton de Gruyter.

Clark, E. V. (1990). On the pragmatics of contrast. *Journal of Child Language*, *17*(2), 417–431. https://doi.org/10.1017/S0305000900013842

Conti, D. J., & Camras, L. A. (1984). Children's understanding of conversational principles. *Journal of Experimental Child Psychology*, *38*(3), 456–463. https://doi.org/10.1016/0022-0965(84)90088-2

Davies, C., & Katsos, N. (2010). Over-informative children: Production/comprehension asymmetry or tolerance to pragmatic violations? *Lingua*, *120*(8), 1956–1972. https://doi.org/10.1016/j.lingua.2010.02.005

De Marchena, A., Eigsti, I. M., Worek, A., Ono, K. E., & Snedeker, J. (2011). Mutual exclusivity in autism spectrum disorders: Testing the pragmatic hypothesis. *Cognition*, *119*(1), 96–113. https://doi.org/10.1016/j.cognition.2010.12.011

De Neys, W., & Schaeken, W. (2007). When people are more logical under cognitive load: Dual task impact on scalar implicature. *Experimental Psychology*, *54*(2), 128–133. https://doi.org/10.1027/1618-3169.54.2.128

Degen, J., & Tanenhaus, M. K. (2015). Processing scalar implicature: A constraint-based approach. *Cognitive Science*, *39*(4), 667–710. https://doi.org/10.1111/cogs.12171

DeLoache, J. S. (1991). Symbolic functioning in very young children: Understanding of pictures and models. *Child Development*, *62*(4), 736–752. https://doi.org/10.1111/j.1467-8624.1991.tb01566.x

DeLoache, J. S. (2000). Dual representation and young children's use of scale models. *Child Development*, *71*(2), 329–338. https://doi.org/10.1111/1467-8624.00148

Diesendruck, G., & Markson, L. (2001). Children's avoidance of lexical overlap: A pragmatic account. *Developmental Psychology*, *37*(5), 630. https://doi.org/10.1037//0012-1649.37.5.630

Diesendruck, G., Markson, L., Akhtar, N., & Reudor, A. (2004). Two-year-olds' sensitivity to speakers' intent: an alternative account of Samuelson and Smith. *Developmental Science*, *7*(1), 33–41.

Eager, C., & Roy, J. (2017). Mixed effects models are sometimes terrible. *arXiv* preprint *arXiv*:1701.04858.

Epley, N., Morewedge, C. K., & Keysar, B. (2004). Perspective taking in children and adults: Equivalent egocentrism but differential correction. *Journal of Experimental Social Psychology*, *40*(6), 760–768. https://doi.org/10.1016/j.jesp.2004.02.002

Fairchild, S., & Papafragou, A. (2018). Sins of omission are more likely to be forgiven in non-native speakers. *Cognition*, *181*, 80–92. https://doi.org/10.1016/j.cognition.2018.08.010

Foppolo, F., Guasti, M. T., & Chierchia, G. (2012). Scalar implicatures in child language: Give children a chance. *Language Learning and Development*, *8*(4), 365–394. https://doi.org/10.1080/15475441.2011.626386

Foppolo, F., & Marelli, M. (2017). No delay for some inferences. *Journal of Semantics*, *34*(4), 659–681. https://doi.org/10.1093/jos/ffx013

Geurts, B. (2010). *Quantity implicatures*. Cambridge: Cambridge University Press.

Girbau, D. (2001). Children's referential communication failure: The ambiguity and abbreviation of message. *Journal of Language and Social Psychology*, *20*(1–2), 81–89. https://doi.org/10.1177/0261927X01020001004

Glucksberg, S., Krauss, R. M., & Higgins, E. T. (1975). The development of referential communication skills. *Review of Child Development Research*, *4*, 305–345.

Grice, H. P. (1975). Logic and conversation. In P. Cole & J. Morgan (Eds.), *Syntax and semantics* (Vol. 3). New York, NY: Academic Press.

Grice, P. (1989). *Studies in the way of words*. Cambridge, MA: Harvard University Press.

Grigoroglou, M., & Papafragou, A. (2018). Acquisition of pragmatics. In R. Clark & M. Aronoff (Eds.), *Oxford research encyclopedia of linguistics*. Online edition. Oxford University Press. https://doi.org/10.1093/acrefore/9780199384655.013.217

Grigoroglou, M., & Papafragou, A. (2019). Interactive contexts increase informativeness in children's referential communication. *Developmental Psychology*. In press. https://doi.org/10.1037/dev0000693

Grodner, D. J., Klein, N. M., Carbary, K. M., & Tanenhaus, M. K. (2010). "Some", and possibly all, scalar inferences are not delayed: Evidence for immediate pragmatic enrichment. *Cognition*, *116*(1), 42–55. https://doi.org/10.1016/j.cognition.2010.03.014

Guasti, M. T., Chierchia, G., Crain, S., Foppolo, F., Gualmini, A., & Meroni, L. (2005). Why children and adults sometimes (but not always) compute implicatures. *Language and Cognitive Processes*, *20*(5), 667–696. https://doi.org/10.1080/01690960444000250

Gweon, H., & Asaba, M. (2018). Order matters: Children's evaluation of underinformative teachers depends on context. *Child Development*, *89*(3), e278–e292. https://doi.org/10.1111/cdev.12825

Hirschberg, J. L. B. (1985). *A theory of scalar implicature*. Ph.D. thesis. Philadelphia, PA: University of Pennsylvania.

Hochstein, L., Bale, A., & Barner, D. (2018). Scalar implicature in absence of epistemic reasoning? The case of autism spectrum disorder. *Language Learning and Development*, *14*(3), 224–240. https://doi.org/10.1080/15475441.2017.1343670

Hochstein, L., Bale, A., Fox, D., & Barner, D. (2016). Ignorance and inference: Do problems with Gricean epistemic reasoning explain children's difficulty with scalar implicature? *Journal of Semantics*, *33*, 107–135. https://doi.org/10.1093/jos/ffu015

Horn, L. (1972). *On the semantic properties of the logical operators in English*. Doctoral diss. UCLA Distributed by IULC, Indiana University.

Horn, L. (1989). *A natural history of negation*. Chicago: University of Chicago Press.

Horowitz, A. C., Schneider, R. M., & Frank, M. C. (2018). The trouble with quantifiers: Exploring children's deficits in scalar implicature. *Child Development*, *89*(6), 572–593. https://doi.org/10.1111/cdev.13014

Huang, Y. T., & Snedeker, J. (2009a). Online interpretation of scalar quantifiers: Insight into the semantics–pragmatics interface. *Cognitive Psychology*, *58*(3), 376–415. https://doi.org/10.1016/j.cogpsych.2008.09.001

Huang, Y. T., & Snedeker, J. (2009b). Semantic meaning and pragmatic interpretation in 5-year-olds: Evidence from real-time spoken language comprehension. *Developmental Psychology*, *45*, 1723–1739. https://doi.org/10.1037/a0016704

Katsos, N., & Bishop, D. V. (2011). Pragmatic tolerance: Implications for the acquisition of informativeness and implicature. *Cognition*, *120*, 67–81. https://doi.org/10.1016/j.cognition.2011.02.015

Kovács, Á. M., Téglás, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, *330*(6012), 1830–1834. https://doi.org/10.1126/science.1190792

Levinson, S. (2000). *Presumptive meanings*. Cambridge, MA: MIT Press. https://doi.org/10.7551/mitpress/5526.001.0001

Liszkowski, U., Carpenter, M., & Tomasello, M. (2008). Twelve-month-olds communicate helpfully and appropriately for knowledgeable and ignorant partners. *Cognition*, *108*(3), 732–739. https://doi.org/10.1016/j.cognition.2008.06.013

Marty, P., Chemla, E., & Spector, B. (2013). Interpreting numerals and scalar items under memory load. *Lingua*, *133*, 152–163. https://doi.org/10.1016/j.lingua.2013.03.006

Matthews, D., Lieven, E., Theakston, A., & Tomasello, M. (2006). The effect of perceptual availability and prior discourse on young children's use of referring expressions. *Applied Psycholinguistics*, *27*, 403–422. https://doi.org/10.1017/s0142716406060334

Nadig, A. S., & Sedivy, J. C. (2002). Evidence of perspective-taking constraints in children's on-line reference resolution. *Psychological Science*, *13*, 329–336. https://doi.org/10.1111/j.0956-7976.2002.00460.x

Noveck, I. (2001). When children are more logical than adults: Experimental investigations of scalar implicature. *Cognition*, *78*, 165–188. https://doi.org/10.1016/s0010-0277(00)00114-1

O'Neill, D. K. (1996). Two-year-old children's sensitivity to a parent's knowledge state when making requests. *Child Development*, *67*(2), 659–677. https://doi.org/10.2307/1131839

Onishi, K. H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science*, *308*(5719), 255–258. https://doi.org/10.1126/science.1107621

Ozturk, O., & Papafragou, A. (2016). The acquisition of evidentiality and source monitoring. *Language Learning and Development*, *12*(2), 199–230. https://doi.org/10.1080/15475441.2015.1024834

Papafragou, A., Friedberg, C., & Cohen, M. (2018). The role of speaker knowledge in children's pragmatic inferences. *Child Development*, *89*, 1642–1656. https://doi.org/10.1111/cdev.12841

Papafragou, A., & Musolino, J. (2003). Scalar implicatures: Experiments at the semantics-pragmatics interface. *Cognition*, *86*, 253–282. https://doi.org/10.1016/s0010

Papafragou, A., & Tantalou, N. (2004). Children's computation of implicatures. *Language Acquisition*, *12*, 71–82. https://doi.org/10.1207/s15327817la1201_3

Perner, J., & Leekam, S. R. (1986). Belief and quantity: Three-year olds' adaptation to listener's knowledge. *Journal of Child Language*, *13*(2), 305–315. https://doi.org/10.1017/S0305000900008072

Piaget, J. (1970). *Science of education and the psychology of the child*. New York, NY: Viking.

Pouscoulous, N., Noveck, I. A., Politzer, G., & Bastide, A. (2007). A developmental investigation of processing costs in implicature production. *Language Acquisition*, *14*(4), 347–375. https://doi.org/10.1080/10489220701600457

Preissler, M. A., & Carey, S. (2005). The role of inferences about referential intent in word learning: Evidence from autism. *Cognition*, *97*(1), B13–B23. https://doi.org/10.1016/j.cognition.2005.01.008

Regier, T. (2005). The emergence of words: Attentional learning in form and meaning. *Cognitive Science*, *29*(6), 819–865. https://doi.org/10.1207/s15516709cog0000_31

Roberts, C. (1996). Information structure in discourse: Towards an integrated formal theory of pragmatics. *Working Papers in Linguistics-Ohio State University Department of Linguistics*, 91–136. https://doi.org/10.3765/sp.5.6

Roberts, C. (2004). Context in dynamic interpretation. In L. Horn & G. Ward (Eds.), *The handbook of pragmatics* (pp. 197–220). https://doi.org/10.1002/9780470756959.ch9

Sauerland, U. (2004). Scalar implicatures in complex sentences. *Linguistics and Philosophy*, *27*, 367–391. https://doi.org/10.1023/b:ling.0000023378.71748.db

Sauerland, U. (2012). The computation of scalar implicatures: Pragmatic, lexical or grammatical? *Language and Linguistics Compass*, *6*, 36–49. https://doi.org/10.1002/lnc3.321

Shatz, M. (1980). Communication. In P. Mussen, J. Flavell, & E. Markman (Eds.), *Handbook of child psychology: Vol. 3: Cognitive Development* (pp. 841–889). New York, NY: Wiley.

Shatz, M., & Gelman, R. (1973). The development of communication skills: Modifications in the speech of young children as a function of listener. *Monographs of the Society for Research in Child Development*, *38*(5), 1–38. https://doi.org/10.2307/1165783

Singh, R., Wexler, K., Astle-Rahim, A., Kamawar, D., & Fox, D. (2016). Children interpret disjunction as conjunction: Consequences for theories of implicature and child development. *Natural Language Semantics*, *24*(4), 305–352. https://doi.org/10.1007/s11050-016-9126-3

Skordos, D., & Papafragou, A. (2016). Children's derivation of scalar implicatures: Alternatives and relevance. *Cognition*, *153*, 6–18. https://doi.org/10.1016/j.cognition.2016.04.006

Southgate, V., Chevallier, C., & Csibra, G. (2010). Seventeen-month-olds appeal to false beliefs to interpret others' referential communication. *Developmental Science*, *13*(6), 907–912. https://doi.org/10.1111/j.1467-7687.2009.00946.x

Sperber, D., & Wilson, D. (1986). *Relevance: Communication and Cognition* (2nd ed. 1995). Cambridge, MA: Harvard University Press

Stalnaker, R. (1979). Assertion. In P. Cole (Ed.), *Syntax and semantics 9* (pp. 315–332). New York: Academic Press.

Stiller, A., Goodman, N. D., & Frank, M. C. (2015). Ad-hoc implicature in preschool children. *Language, Learning, and Development*, *11*, 176–190. https://doi.org/10.1080/15475441.2014.927328

Tieu, L., Romoli, J., Zhou, P., & Crain, S. (2015). Children's knowledge of free choice inferences and scalar implicatures. *Journal of Semantics*, *33*(2), 269–298. https://doi.org/10.1093/jos/ffv001

Uttal, D. H., O'Doherty, K., Newland, R., Hand, L. L., & DeLoache, J. (2009). Dual representation and the linking of concrete and symbolic representations. *Child Development Perspectives*, *3*(3), 156–159. https://doi.org/10.1111/j.1750-8606.2009.00097.x

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