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The Acquisition of Epistemic Modality: From Semantic Meaning to Pragmatic Interpretation

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Three experiments investigated the acquisition of English epistemic modal verbs (e.g., *may, have to*). Semantically, these verbs encode possibility or necessity with respect to available evidence. Pragmatically, the use of weak epistemic modals often gives rise to scalar conversational inferences (e.g., "The toy may be under the sofa" implies that it is not certain that the toy is under the sofa). Experiment 1 showed that children between the ages of 4 and 5 have mastered key aspects of epistemic modal semantics but have difficulties with contexts involving epistemic possibility. Experiment 2 showed that 4–5-year-olds prefer stronger/more informative over weaker modal statements in contrastive contexts if the stronger statements are warranted by the evidence. Experiment 3 further demonstrated that children of this age can draw pragmatic inferences from the use of weak epistemic modal verbs in contexts that do not involve overt pragmatic judgments. Taken together, these findings throw light on the acquisition of epistemic modality and have implications for the development of the semantics-pragmatics interface.

This article is concerned with the acquisition of epistemic modal verbs such as *may* and *have to* that are typically used to convey what is possible or necessary given the available evidence (e.g., "It may rain tomorrow," "These have to be Julia's parents"). The acquisition of epistemic modality has been the topic of intense investigation because children's ability to entertain concepts of possibility and necessity is of central concern to developmental psychology (e.g., Braine & Rumain, 1983; Piaget & Inhelder, 1975; Shtulman & Carey, 2007). Furthermore, children's ability to use epistemic modal verbs has been linked to the development of theory of mind and early communicative competence (Moore, Pure, & Furrow, 1990; Papafragou, 1998).

Despite the strong interest in this area, prior developmental work has often proceeded independently from the large literature within theoretical linguistics and the philosophy of language that has studied the formal properties of modal verbs (e.g., von Fintel, 2006; Kratzer, 1981; Portner, 2009; and next section). As a result, the developmental literature on epistemic modality has not always separated logico-semantic from pragmatic-contextual contributions to modal meaning

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(see, e.g., Byrnes & Duff, 1989). Furthermore, there have been limited systematic attempts to compare children's understanding of modal language across different contexts and tasks.

In this article, we present a series of three experiments on young children's acquisition of epistemic modality that seek to fill these gaps. We adopt a clear distinction between semantic and pragmatic contributions to modal meaning and use this distinction to assess both the learning problem posed by modals and the processes through which children solve this problem. Furthermore, we use the semantics-pragmatics distinction to inform the design of novel tasks that broaden the empirical basis for understanding the acquisition of modal language. To preface our experimental investigation, in the remainder of this Introduction, we outline linguistic theories of the semantics and pragmatics of epistemic modals, review what is known about the acquisition of these aspects of modal meanings, and introduce the specific research questions motivating our experiments.

LINGUISTIC BACKGROUND: SEMANTICS AND PRAGMATICS OF EPISTEMIC MODALITY

Semantically, epistemic modality concerns what is possible or necessary given the available evidence (Egan & Weatherson, 2011; Hintikka, 1969; Kratzer, 1981; Papafragou, 2000; Portner, 2009; von Fintel, 2006).[1] For instance, imagine that John and Mary are trying to find a missing toy. If John says, "The toy has to be under the sofa," he means that there is evidence from which it follows that the toy is under the sofa (e.g., Mary and he have exhausted all other possible places the toy could be in). If John says, "The toy may be under the sofa," he simply communicates that, according to available evidence, it is possible that the toy is under the sofa (i.e., this conclusion is compatible with existing evidence).

Pragmatically, epistemic modal verbs typically give rise to various conversational inferences. For instance, if Mary hears John utter, "The toy may be under the sofa," she might take his utterance to mean that (he believes that) the toy does not *have to* be under the sofa. How are such pragmatic inferences derived? According to the standard analysis, modal terms form a scale (< *have to/must, should, . . . , may* >) defined in terms of informational/logical strength (Horn, 1972). A statement with a relatively weak term such as *may* in (1) is entailed by the statement containing the stronger term *have to* in (2) but not vice versa:

(1)   The toy may be under the sofa.
(2)   The toy has to be under the sofa.

Let us assume that participants in a conversational exchange strive to make their contribution as informative as is required for the current purposes of the exchange (first maxim of Quantity; Grice, 1989), and that they do not say things for which they lack evidence (second maxim of Quality; Grice, 1989). Upon hearing (1), the hearer may wonder why the speaker used a relatively weak term from the modal scale, when the statement containing the stronger modal in (2) would have been more informative and relevant (thereby apparently violating the first maxim

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[1]Epistemic modality differs from deontic modality which indicates necessity or possibility of actions, for example, obligation and permission (*The students may leave the classroom after submitting their homework, I must/have to see the doctor tomorrow*). Since the two kinds of modality are often encoded by the same expressions cross-linguistically (Papafragou, 2000), the phrase 'epistemic modal verbs' in this paper refers to epistemic *interpretations* of modal verbs.

of Quantity). It is reasonable to conclude that the speaker did so because he lacks evidence for the stronger modal statement in (2) (thereby observing the second maxim of Quality) – that is, the speaker does not believe that the stronger statement holds (see (3)):

(3)   The speaker does not believe that the toy has to be under the sofa.
      Formally: $\neg BEL_s$(have to p)   (where p is the bare proposition)

Assuming that the speaker knows something about the location of the toy (the *Competence Assumption*; see Horn, 1989; Sauerland, 2004; Soames, 1982; Spector, 2006; van Rooij & Schulz, 2004, for versions of this idea), the conclusion in (3) can be strengthened to (4) (i.e., one might infer that the speaker actually believes that the stronger modal statement *does not* hold), which in turn can be strengthened to (5) (Franke, 2011):[2]

(4)   The speaker believes that the toy does not have to be under the sofa.
      Formally: BEL_s(¬have to p)
(5)   The toy does not have to be under the sofa.
      Formally: ¬(have to p)

The family of conversational inferences in (3)–(5) that lead from the use of *may* to (several versions of) the negation of the stronger scalar alternative *have to* are known as *scalar implicatures* (see also Carston, 1990; Chierchia, 2004; Chierchia, Fox, & Spector, in press; Gazdar, 1979; Geurts, 2010; Hirschberg, 1985; Levinson, 2000; Sauerland, 2004, 2012; Spector, 2006; Sperber & Wilson, 1986; van Rooij & Schulz, 2004, for varying perspectives).

The use of modal terms often gives rise to an additional kind of inference. Consider again the modal statements in (1)–(2). In both cases, the speaker appears to stake himself to a weaker claim than the bare, unmodalized proposition in (6):

(6)   The toy is under the sofa.

In general, there is the strong intuition that, when uttering an epistemic modal statement such as (1) or (2), the speaker lacks direct (visual) evidence or trustworthy reports that would allow him to simply say (6) and can therefore only make an indirect inference. For instance, if the speaker had directly seen that the toy was under the sofa, it would have been odd to say that the toy might be or had to be under the sofa. The intuition of reduced speaker commitment, especially for an utterance such as (2), is unexpected on the standard semantic account of modality (e.g., Kratzer, 1981), according to which statements containing necessity modals such as *must* and *have to* are logically stronger than (i.e., entail) the bare proposition (even though see Kratzer, 1991, for a proposal). This problem has been discussed extensively in the linguistics literature (for a summary, see von Fintel & Gillies, 2010; cf. also Papafragou, 2006a).

At present, there is no consensus among theorists as to how the "weak commitment" intuition is derived from (1) or (2). One possibility would be to consider it a type of scalar implicature.

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[2]If the hearer does not accept the Competence Assumption, then (3) can be strengthened to (4'), according to which the speaker cannot commit to either the stronger modal proposition in (2) or to its negation (Geurts, 2010):

(4')   The speaker does not believe that the toy has to be under the sofa and he does not believe that the toy does not have to be under the sofa.
       Formally: $\neg BEL_s$(have to p) Λ $\neg BEL_s$(¬have to p)

Essentially (4') conveys that the speaker has no opinion as to whether the stronger proposition is true or not. We will not discuss this type of inference further here.

This line of reasoning starts with the observation that the speaker, by using an epistemic modal statement such as (1) or (2), did not assert the bare proposition in (6) and concludes (through various intermediate steps) that the speaker therefore lacks direct evidence for the bare proposition. One problem with this approach is that the assertion of (6) does not, in fact, convey that the speaker *has* direct or trustworthy evidence (e.g., has seen) that the toy is under the sofa – and so such an attempt to compute a scalar implicature by contrasting (1) or (2) with (6) cannot get off the ground (see von Fintel & Gillies, 2010). An alternative approach is to assume that epistemic modals carry the presupposition that the direct, trustworthy information available in a context does not settle the question whether the bare proposition is true or not (von Fintel & Gillies, 2010). The presupposition analysis has the advantage, among other things, of capturing the fact that statements with *must/have to* communicate weaker claims compared with unmodalized statements when direct evidence is valued more strongly than inferential evidence (as in (6))—but may in other cases appear stronger than unmodalized statements if logical/inferential evidence is valued more highly than observation (as is sometimes the case in scientific reasoning). One disadvantage of this approach is that, unlike the scalar implicature account, it treats what appears to be a robust inference across modals within and across languages as a mere stipulation in the lexical semantics of each modal (von Fintel & Gillies, 2010). In what follows, we do not take a position on the specifics of the derivation of what we call the *indirectness* inference. We simply assume that this type of inference is compatible with the standard treatment of modal semantics (Kratzer, 1981), provided this treatment is supplemented with appropriate pragmatic machinery.

To learn epistemic modal terms, children need to acquire both the semantic aspects of modal meaning (including the notions of possibility and necessity) and the ability to compute pragmatic (both scalar and indirectness) inferences from the use of modal expressions. As mentioned already, prior work on the acquisition of modality has not always separated logico-semantic from pragmatic contributions to modal meaning. For instance, Byrnes and Duff (1989) assert that an understanding of the 'certainty implications' carried by modals should be taken as equivalent to a logical understanding, thereby ignoring the pragmatics-driven mechanisms outlined earlier. In the following sections, we use the semantics-pragmatics distinction to organize what is known about the acquisition of epistemic modal meaning and identify the specific research questions that motivate the present work.

ACQUISITION OF EPISTEMIC MODAL SEMANTICS

Several spontaneous production studies suggest that the acquisition of epistemic modals in English is slow and protracted (O'Neill & Atance, 2000; Perkins, 1983; Wells, 1979). However, few studies have used comprehension tasks to systematically examine children's understanding of the semantics of modal verbs (Noveck, 2001; Noveck, Ho, & Sera, 1996). In one such study (Noveck, 2001, Exp. 1), 5-, 7-, 9-year-olds and adults were presented with two open boxes, one containing a parrot and the other a parrot and a bear, and a covered box that was said to have the same contents as one of the two open boxes. Next, a puppet offered a series of modal statements about the content of the covered box (e.g., "There has to be a parrot in the box") and participants were asked to say whether they agreed or disagreed. Findings show that 7- and 9-year-olds but not 5-year-olds showed mastery of epistemic modal meanings. For instance, even though the younger

children were above chance levels when they had to reason about a necessary conclusion (e.g., whether there could/had to be a parrot in the box), they were at chance levels when they had to evaluate the truth of a simply possible conclusion (e.g., whether there could be a bear in the box). This assessment is consistent with prior findings in the literature suggesting that children have difficulty with the situations involving epistemic possibility – more specifically, situations that can have alternative possible outcomes (e.g., Byrnes & Overton, 1986; Green, 1979; Piaget & Inhelder, 1975; Piéraut-Le Bonniec, 1980; Shtulman & Carey, 2007; but see Braine & Rumain, 1983).

One issue with prior tasks used to evaluate knowledge of epistemic necessity and possibility is that they often required children to hold multiple pieces of information in mind (e.g., Noveck, 2001; Noveck et al., 1996; Piéraut-Le Bonniec, 1980). For instance, Noveck's (2001) task involved three boxes and a complex rule about how the contents of the boxes were related. It seems important to investigate children's sensitivity to logical aspects of modality using a simpler setup (e.g., one with only two boxes and a lighter memory component).

Furthermore, prior tasks typically asked children to evaluate modal statements against situations with possible or necessary outcomes. It would be worth investigating children's interpretation of modals such as *may* and *have to* in utterances that include, but are not limited to, statements. To the extent that children's semantic intuitions about epistemic modals are robust, they should persist across different syntactic/semantic environments. Alternatively, some patterns found in earlier studies might be specific to the syntactic environment of the modals: for instance, children might respond differently to modal statements ("There has to be a bear in the box") compared to modal questions ("Does there have to be a bear in the box?"), since the first— but not the second—type of utterance can be interpreted as the speaker's guess that the child may not wish to challenge. In the experimentation that follows, we address these issues in a way to be made more precise below.

ACQUISITION OF EPISTEMIC MODAL PRAGMATICS

Turning to the pragmatics of epistemic modality, previous studies suggest that children cannot spontaneously generate scalar implicatures from the use of epistemic modals. In Noveck's (2001) reasoning task reported above, 5-, 7-, and 9-year-olds, unlike the majority of adults, accepted true but underinformative statements (e.g., "There might be a parrot in the box") when stronger/more informative statements (e.g., "There has to be a parrot in the box") would also have been true. Subsequent studies confirmed this pragmatic difficulty using evidence from other scalar expressions such as quantifiers and aspectuals (Noveck, 2001, Exp. 3; Gualmini, Crain, Meroni, Chierchia, & Guasti, 2001; Guasti et al., 2005; Huang & Snedeker, 2009; Papafragou, 2006; Papafragou & Musolino, 2003). Further evidence showed that children's inability to compute scalar implicatures is not due to complete lack of pragmatic sophistication: the clarity of the experimental goals, the salience of available alternatives and the type of response (verbal vs. action) affect 5-year-olds' sensitivity to scalar implicatures (Barner & Bachrach, 2010; Barner, Brooks, & Bale, 2011; Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Foppolo, Guasti, & Chierchia, 2012; Guasti et al., 2005; Huang & Snedeker, 2009; Katsos & Bishop, 2011; Papafragou, 2006b; Papafragou & Musolino, 2003; Papafragou & Tantalou,

2004; Pouscoulous, Noveck, Politzer, & Bastide, 2007). These later results have been based on scales involving disjunction (< *and, or* >) or quantification (<*all, most, . . . , some* >) but not modality.

In a study that is particularly relevant to present purposes (Chierchia et al., 2001), preschoolers were presented with a weak scalar statement containing disjunction ("Every farmer cleaned a horse or a rabbit") in a context in which a stronger scalar alternative was true (e.g., where every farmer cleaned *both* a horse *and* a rabbit). Only half of the children successfully rejected the weak statement despite its pragmatic infelicity. Nevertheless, when children of the same age were given a choice between a strong and a weak scalar statement describing the story outcome ("Every farmer cleaned a horse or a rabbit" vs. "Every farmer cleaned a horse and a rabbit"), they overwhelmingly picked the stronger/more informative statement. It appears that young children are sensitive to differences in informativeness between weak and strong scalars (a prerequisite for computing scalar implicatures), at least when scalars are contrasted to each other. However, children may be unable to spontaneously access stronger alternatives and use them to compute implicatures when asked to judge scalar sentences in isolation.

Does this conclusion generalize to epistemic modals? Notice that prior studies asked children to judge modal statements without supporting context (e.g., Noveck, 2001) and may have thus underestimated children's underlying pragmatic abilities. There is some evidence that, in contrastive contexts, young children appreciate subtle properties of weak and strong epistemic modal verbs. In a classic experiment by Hirst and Weil (1982), children between the ages of 3 and 6 had to guess the location of a hidden object by listening to two puppets that gave different statements about where the object was. The statements contained either two epistemic modals (e.g., "The peanut must be under the box" vs. "The peanut may be under the cup") or an epistemic modal and a plain assertion (e.g., "The peanut may be under the cup" vs. "The peanut is under the box"). The question was whether children would consistently pick the location indicated by the stronger modal statement when two modals were contrasted, or the location indicated by the plain assertion when the assertion contrasted with a modal. It was found that young 3-year-olds were already above chance at choosing locations indicated by plain assertions over *may* and older 3-year-olds were above chance at choosing locations indicated by *must* over *may*. More subtle contrasts were acquired later, such that older 5-year-olds could reliably distinguish between the modals *may, must, should,* and between each modal and the corresponding plain assertion. Further studies with the same basic method confirmed that 5-year-olds understand the *may*/*have to* and *may*/plain assertion difference (but not the *must*/plain assertion difference: Noveck et al., 1996, Exp. 1; see also Byrnes & Duff, 1989; Moore, Bryant, & Furrow, 1989; Moore & Davidge, 1989; Moore et al., 1990; Moore & Furrow, 1991). Thus some sensitivity to pragmatic properties of epistemic modals, at least in contrastive contexts, seems to be present in children early on.

Notice that, unlike Chierchia et al.'s work on disjunction discussed earlier, Hirst and Weil's method did not take into account how evidence bears on the evaluation of a modal statement (children chose between two statements in the absence of a scene). Thus this method does not reveal whether children can pragmatically evaluate whether the conversational contribution of different modals (or modals vs. plain assertions) is appropriate *given what the speaker believes/has evidence for.* As already mentioned, the ability to take into consideration speaker belief and evidence is an important step for both scalar and indirectness inferences.

Furthermore, in Hirst and Weil's and later studies, correct responses always involved choosing the stronger modal term (or the assertion, in modal/assertion contrasts), but never a weak modal. Therefore, it is possible that correct answers reflected a bias to choose the strong statement without deep processing of the incoming stimuli. In a related study (Noveck et al., 1996, Exp. 2), 5-year-olds (but not 7-year-olds) sometimes failed to choose logically true modal statements over false ones of equal or higher strength, presumably because of the pull of the stronger statement (e.g., children failed to choose "There may be a parrot in the box" over "There has to be a bear in the box" in a scenario where there *had to* be a parrot in the box). Thus the question whether young children can flexibly distinguish between epistemic modals of different strength (e.g., *have to* vs. *may*) or assertions with and without a modal in accordance with available evidence remains open. We take up these issues in our own investigation of the pragmatics of epistemic modality reported below.

EXPERIMENTAL PROSPECTUS

In what follows, we present three experiments that systematically tested children's comprehension of semantic and pragmatic aspects of epistemic modal meanings. In Experiment 1, we used a novel modal reasoning task to test 4- to 5-year-old children's comprehension of the semantics of epistemic modality. Unlike prior tasks used to evaluate knowledge of necessity and possibility that required children to hold multiple pieces of information in mind (e.g., Noveck et al., 1996; Piéraut-Le Bonniec, 1980), this design presented children with a simple task. We were particularly interested in broadening the empirical basis for investigations of modal language by testing modality comprehension in a variety of syntactic/semantic environments (statements as well as questions).

In Experiment 2, we focused exclusively on children's sensitivity to pragmatic inferences from the use of epistemic modals. Inspired by Chierchia et al.'s (2001) study that used contrast as a way of testing sensitivity to the pragmatic implications of scalars, we asked whether, presented with two true epistemic modal statements of differing strength, 4- and 5-year-old children can choose the stronger/more informative one. Additionally, we asked whether children, presented with a choice between epistemic modals and bare assertions, would choose assertions when direct evidence for the truth of the bare proposition was available (in accordance with the indirectness inference). Unlike prior studies (e.g., Hirst & Weil, 1982), the choice between statements was guided by the evidence available to the speaker at the moment of speaking.

In Experiment 3, we investigated children's sensitivity to modal pragmatics with a different method. Specifically, we asked whether children can detect pragmatic differences between an epistemic modal statement and a plain, unmodalized one in a situation where the statements themselves have strong positive or negative consequences. This design moved beyond Experiment 2, since it did not involve an explicit pragmatic judgment about the appropriateness of two utterances. Also, unlike our earlier study (and designs such as Hirst and Weil's that have been extensively adopted in the literature), correct responses involved alternating between choosing a modal and a non-modal statement, thereby yielding a stronger test of modal understanding. Together, these experiments throw light on how young children acquire aspects of modal meaning and how early semantic knowledge and pragmatic ability might differ from (and ultimately lead to) adult-like knowledge of modality.

EXPERIMENT 1: ASSESSING EPISTEMIC MODAL SEMANTICS

The first experiment systematically explored young children's semantic interpretation of the epistemic modal verbs *may* and *have to* using a variety of modal scenarios. Four- to five-year-old children and a group of adult controls were presented with simple stories that gave different cues about the location of an animal. In the Statement condition, participants heard a modal statement (e.g., "The cow has to be in the orange box") and had to say whether they agreed or not. Half of the participants in the Statement condition heard sentences with a possibility modal (*may*) and the other half sentences with a necessity modal (*have to*). Of interest was whether children would consider different types of evidence and their connection to possible and necessary inferences such that they could accept true modal statements and reject false ones. Because we were mostly interested in logical, not pragmatic, interpretations of the modals, we presented the two types of modal (*may, have to*) to separate groups of participants so as to discourage access to modal alternatives (unlike, e.g., Noveck, 2001).

To ensure that children's responses to the modal statements reflected genuine semantic intuitions, we also included a Question prompt in which a separate group of participants was presented with the same propositions in interrogative form (e.g., "Does the cow have to be in the orange box?") and had to answer with *Yes* or *No*. To the extent that children's knowledge of epistemic modal semantics was robust, performance should be similar across the Statement and Question prompts. Otherwise, performance might diverge across the two prompts. For instance, children might be willing to engage in guessing, and/or assent to another speaker's modal statement in the face of uncertainty. In that case, they might be more likely to offer *Yes* responses to modals in the Statement compared to the Question prompt.

Method

Participants.   A total of 48 English-speaking-children (20 female and 28 male, mean age 5;1, ranging from 4;6 to 6;0) and 40 adults (20 female and 20 male) participated. The child participants were recruited from preschools in Newark, Delaware. The adults were undergraduate students at the University of Delaware enrolled in an introductory psychology course.

Stimuli and procedure.   Participants were presented with short animated stories on a computer screen. At the beginning of the session the experimenter told participants that they would play a game. In this game, they would see stories on the computer. In each story, an animal would hide in a box. The animals could only hide in boxes and nowhere else. Participants were randomly assigned to either the Statement or the Question prompt. In the Statement prompt, participants were told that, after each animal would hide, the experimenter would tell them something about where the animal was and they would have to say "if they agreed or not." In the Question prompt, participants were told that, after each animal would hide, the experimenter would ask them a question about where the animal was and they would have to answer with *Yes* or *No*. Within each prompt group, half of the participants heard stimuli with a possibility modal (*may/can; P-modal* condition) and the other half heard stimuli with a necessity modal (*have to; N-modal* condition). Because epistemic *may* cannot be used in interrogative-initial position in English, we used *can* in the Question prompt of the P-modal condition. *Can* is known to carry epistemic meaning in

some contexts (e.g., "Sandy cannot be home"; von Fintel, 2006), even though such uses are limited. In all condition/prompt combinations, the modal verb received contrastive stress. Children's mean age did not differ across the 4 condition/prompt groups.

There were four different types of story (for examples, see Table 1). In the first type, only one box was on the stage and participants had to infer that the animal had necessarily ended up in that box. In the second story type, there were two boxes on the stage. After the animal had hid, one of the boxes was opened and found empty. Test prompts targeted the open box. In the third story type, two boxes were on the stage and both boxes remained unopened. The test statement/question targeted one of the unopened boxes which was a possible (but not necessary) location for the animal. Finally, the fourth story type involved two boxes, one of which was opened and found empty. Test statements/questions targeted the unopened box which, according to logical inference, was the necessary hiding place of the animal. In sum, Story types 1, 2, and 4 had determinate outcomes (the location of the animal could be inferred with certainty), whereas Story type 3 had an indeterminate outcome (the location of the animal was uncertain).

Table 1 presents the expected (logical) responses to the test prompts. Notice that some of the logically true test statements were pragmatically infelicitous: in the P-modal condition in Story types 1 and 4, modal statements were underinformative (i.e., there was evidence that the animal *had to* be in a specific box but the prompt simply said that the animal *might* be in that box). For present purposes, the pragmatic potential of such statements was set aside and they were simply considered true (see Table 1).

Three stories for each type were created for a total of 12 stories. Stories were administered in a fixed order. When stories involved two boxes, the position of the target box (left-right) was counterbalanced within participants.
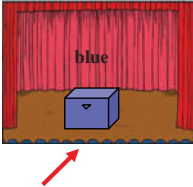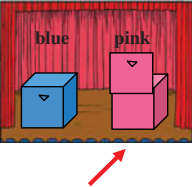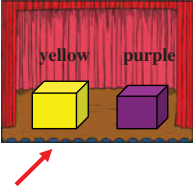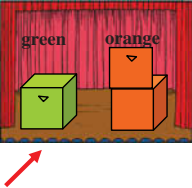
Results

The results, which are presented in Table 1, confirm that both children and adults treated the present task in semantic, not pragmatic, terms: participants accepted logically true but underinformative modal propositions (see P-modal condition in Story Types 1 and 4).

A MANOVA with Age (Children, Adults), Condition (P-modal, N-modal) and Prompt (Statement, Question) as between-subjects variables and Story Type (1, 2, 3, 4) as a within-subjects variable and percent correct as the dependent variable revealed a main effect of Age ($F (1, 80) = 59.35$, $p < .0001$), a main effect of Prompt ($F (1, 80) = 7.27$, $p = .008$), and an Age by Prompt interaction ($F (1, 80) = 8.13$, $p = .005$). Furthermore, the analysis revealed a main effect of Story Type ($F (3, 78) = 15.61$, $p < .0001$), as well as an interaction between Age and Story Type ($F (3, 78) = 15.52$, $p < .0001$), and a marginal interaction among Age, Prompt, and Story Type ($F (3, 78) = 2.15$, $p = .09$). No other main or interaction effects were significant.

The interaction between Age and Prompt was due to the fact that, for adults, there was no difference between the Statement and Question prompts since performance was always at ceiling ($M_S = 99\%$ vs. $M_Q = 99.5\%$). For children, however, the Statement prompt yielded better performance compared to the Question prompt ($M_S = 86\%$ vs. $M_Q = 71\%$; $p < .05$). The marginal interaction between Age, Prompt and Story Type gives some indication that the Statement-Prompt difference for children was absent in Story Type 2, where prompts targeted the open box

TABLE 1
Design Summary and Results (Mean Percent Correct and Standard Deviation) for Experiment 1

Story Types (arrow marks box targeted by prompt)

Type 1	Type 2	Type 3	Type 4
blue	blue pink	yellow purple	green orange

Statements/Questions (X = name of animal)	Logical response (both S and Q)	Age group	
		Children	Adults
P-modal Condition			
Story Type 1			
S: "The X may be in the blue box."	Yes	100* (00)	100* (00)
Q: "Can the X be in the blue box?"		94* (13)	100* (00)
Story Type 2			
S: "The X may be in the pink box."	No	80* (30)	100* (00)
Q: "Can the X be in the pink box?"		78* (41)	100* (00)
Story Type 3			
S: "The X may be in the yellow box."	Yes	86* (22)	100* (00)
Q: "Can the X be in the yellow box?"		44 (38)	100* (00)
Story Type 4			
S: "The X may be in the green box."	Yes	94* (13)	97* (10)
Q: "Can the X be in the green box?"		78* (26)	100* (00)
N-modal Condition			
Story Type 1			
S: "The X has to be in the blue box."	Yes	100* (00)	100* (00)
Q: "Does the X have to be in the blue box?"		89* (16)	97* (10)
Story Type 2			
S: "The X has to be in the pink box."	No	86* (33)	100* (00)
Q: "Does the X have to be in the pink box?"		78* (41)	100* (00)
Story Type 3			
S: "The X has to be in the yellow box."	No	53 (44)	97* (10)
Q: "Does the X have to be in the yellow box?"		44 (32)	100* (00)
Story Type 4			
S: "The X has to be in the green box."	Yes	89* (29)	100* (00)
Q: "Does the X have to be in the green box?"		64 (41)	100* (00)

Note. Asterisks indicate means significantly different from chance levels; $p < .05$. (Color figure available online.)

($M_S = 84\%$ vs. $M_Q = 80\%$), but present in the other three Story Types, where prompts targeted the invisible contents of a closed box (1: $M_S = 100\%$ vs. $M_Q = 86\%$; 3: $M_S = 70\%$ vs. $M_Q = 48\%$; 4: $M_S = 85\%$ vs. $M_Q = 75\%$; independent samples t-tests, all $ps < .05$). Since only one sixth of the correct responses in these three Story Types was *No*, it appears that the increase in the

percentage of correct responses for statements compared to questions might be simply due to the fact that children were more willing to respond *Yes* to utterances that could be construed as bets or guesses, especially when such utterances targeted unobservable contents. Indeed, an ANOVA comparing the proportion of children's *Yes* responses to the two prompts collapsing across Stories 1, 3, and 4 revealed a main effect of Prompt (F (1, 47) = 14.68, p = .0004, M_S = 87% vs. M_Q = 69%).

Furthermore, the interaction between Age and Story Type occurred because adults were equally good regardless of Story Type (M_1 = 99%, M_2 = 100%, M_3 = 99%, M_4 = 99%) but children performed differently across Story Types (M_1 = 96%, M_2 = 80%, M_3 = 57%, M_4 = 81%; F (3, 45) = 17.29, p < .0001). Matched-pairs comparisons revealed that, with the exception of Story Types 2 and 4 (t(47) = .12, p = .89, n.s.), different Story Types led to different performance in children (1 vs. 2: t(47)=−2.68, p = .01; 2 vs. 3: t(47) = −3.36, p = .001; 3 vs. 4: t(47) = 3.70, p = .0006; 1 vs. 4: t(47) = −3.29, p = .001; 1 vs. 3: t(47) = −7, p < .0001). Thus children performed most accurately when there was a single (unopened) box on the stage and thus the animal had to be in that box (Story Type 1). Situations in which one of the two boxes was opened and found empty, and therefore the location of the animal (in the other box) could be inferred with certainty, elicited less accurate responses (Story Types 2 and 4). Children performed least accurately when both boxes were unopened and there was uncertainty as to where the animal was (Story Type 3).

Comparisons of participants' performance against chance (see Table 1) confirm these patterns. As expected, adults' performance was consistently different from chance. Children's performance was different from chance in all Prompt by Condition combinations for Story Types 1, 2, and 4 (with the exception of the Question prompt in the P-modal condition of Story Type 4). However, for Story Type 3, where the outcome was uncertain/indeterminate, performance differed from chance in only one of the four Prompt by Condition combinations (the Statement prompt in the P-modal condition, even though not the Question prompt). Thus indeterminate outcomes seem to represent a particularly difficult area of modal scenarios, a point to which we return below.

Discussion

Unlike prior tasks used to evaluate knowledge of necessity and possibility that required children to hold multiple pieces of information in mind (e.g., Noveck et al., 1996; Piéraut- Le Bonniec, 1980), here we presented children with a simple task in which they had to reason about the location of a hidden animal and evaluate modal language involving *may* and *have to*. Results show that 4- to 5-year-olds have made some progress in acquiring the semantics of the two modals, since they mostly succeeded in offering logically correct responses to modal questions and statements containing *may*/*have to* at levels above chance. Nevertheless, 4- to 5-year-olds, unlike adults, were not equally accurate in their semantic judgments of epistemic modals across different syntactic environments. Specifically, children were more accurate at evaluating modal statements about the location of an animal ("The cow may/has to be in the blue box") compared to answering questions ("Can/does the cow have to be in the blue box?"; M_S = 86% vs. M_Q = 71%). This difference appears to be related to children's tendency to respond *Yes* to modal utterances that could be construed as guesses about the unobservable location of the animal (this tendency was reduced

for questions, which cannot act as guesses).[3] The fact that children's interpretation of epistemic modals depends on the syntactic-semantic environment suggests that children's understanding of modality is not yet robust.

Furthermore, children, unlike adults, were not equally accurate in their semantic judgments across different Story Types (or modal scenarios). Children were most accurate in Story Type 1 (M = 96%), in which there was a single (unopened) box on the stage and thus the animal had to be in that box. Children were less accurate in Story Types 2 and 4 (M = 80% and 81% respectively), in which one of the two boxes was opened and found empty, and therefore the animal had to be in the other box. Just like Story Type 1, Story Types 2, and 4 involved a necessary outcome. Unlike Story Type 1, however, the evidence for this outcome accumulated during the trial (after one of the boxes was opened), and this presumably accounts for the fact that these Story Types were more difficult for children. The most problematic was Story Type 3 (M = 57%): before either of the boxes on the stage had been opened, children had trouble recognizing that it was simply *possible,* but not *necessary,* for the animal to be in a specific box.

Children's errors in Story Type 3 are reminiscent of evidence in the developmental literature according to which, even though young children recognize that a situation may have multiple possible outcomes (Fabricius, Sophian, & Wellman, 1987; Sophian & Somerville, 1988), they have trouble reasoning about such outcomes under conditions of uncertainty (Bindra, Clarke, & Shultz, 1980; Byrnes & Overton, 1986; Fay & Klahr, 1996; Green, 1979; Horobin & Acredolo, 1989; Klahr & Chen, 2003; Piéraut-Le Bonniec, 1980; Robinson, Rowley, Beck, Carroll, & Apperly, 2006). In one study (Robinson et al., 2006), 5-year-olds were presented with a toy wall with a green, a yellow and a black door, as well as with two bags, a black one containing only black blocks and a green-and-yellow one containing an equal number of green and yellow blocks. Children were told that the experimenter would choose a block and push it through one of the doors, such that the block and the door would be of the same color; their task would be to place trays under the doors to catch the block. When the children saw the experimenter choose a block from the black bag (i.e., when they could infer that the block was black), they successfully placed a tray under the black door; but when the experimenter chose a block from the green-and-yellow bag (i.e., when the block could have been either green or yellow), children failed to place trays under both the green and yellow door but instead chose one of the two doors to place a tray under. This tendency to treat an indeterminate state of affairs as determinate (also known as "premature closure"; Acredolo & Horobin, 1987) reflects children's limitations in dealing with epistemic uncertainty.

In light of these prior experiments, not all of which involved modal language (cf. Robinson et al., 2006), we conclude that children's failures with modals in Story Type 3 are not simply of a linguistic-semantic nature but are rather another manifestation of an underlying difficulty with epistemically indeterminate states of affairs. To pass the trials in this Story type, as well as

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[3]Throughout this experiment we have assumed that both children and adults interpret modals with respect to the common evidence about the animal's location. However, children might be reluctant to reject epistemic modal claims made by someone else, reasoning that the speaker might have private reasons/beliefs/hunches for making a claim, which they do not have access to. This alternative (or perhaps complementary) hypothesis is inspired by the distinction between subjective and objective epistemic modality in the linguistics literature (Papafragou, 2006a; Portner, 2009; von Fintel & Gillies, 2010). The hypothesis correctly predicts the observed difference in the way children respond when evaluating a modal statement made by someone else versus when asked a question about their own assessment of the evidence.

similar tasks in prior studies, children need to keep in mind distinct possibilities (i.e., that the animal may be in either of the two boxes) and postpone committing to a single conclusion unless more evidence becomes available - an ability which may not be fully in place before age 9 or later (Acredolo & Horobin, 1987; Bindra et al., 1980; Byrnes & Overton, 1986; Piéraut-Le Bonniec, 1980; cf. also Noveck, 2001).

An important assumption behind Experiment 1 was that both adults and children should treat it as a semantic task and thus overwhelmingly accept logical over pragmatic interpretations of under-informative (weak) modal statements. This expectation was confirmed in our data. Specifically, in Story Types 1 and 4 (P-modal condition), where, given the visual evidence and the rules of the game, the animal *had to* be in a specific box, both children and adults agreed with the statement that the animal *might* be in that box. Two factors were likely to have contributed to such performance. First, participants were exposed to a single modal term and were thereby not encouraged to consider other modal alternatives (in a related task in which both possibility and necessity modals were presented to participants, rates of pragmatic responding were higher, even though children were less likely to respond pragmatically than adults; Noveck, 2001, Exp. 1). Second, even if participants considered more felicitous alternatives, the task set-up did not provide the option of saying that *has to* was a better option than *may* (see also Noveck, 2001; Exp. 2, for another demonstration that task features can increase logical interpretations of epistemic modals).

If children's (and adults') pragmatic blindness in Experiment 1 was truly task-induced, it should be possible to show that, under different experimental circumstances, children and adults are able to distinguish between two modals (or a modal and a plain, unmodalized assertion) that differ in pragmatic felicity. In Experiment 2, we modified the design of Experiment 1 to present scalar alternatives contrastively with the goal of examining this issue.

Experiment 2 also served a secondary goal. Recall that Experiment 1 revealed no overall difference in children's (or adults') performance with *may* vs. *have to* (i.e., Condition—P-modal or N-modal—entered into no main effects or interactions).We took this finding to mean that children's difficulties with epistemic modals were not tied to specific lexical items but stemmed from the underlying conceptual analysis of different story types/outcomes. However, since Experiment 1 did not find evidence that children responded differently to *may* and *have to* in any way, an alternative possibility is that children could not distinguish between the two modals and/or ignored the modals and responded only on the basis of the embedded (bare) proposition (e.g., they interpreted "The animal may/has to be in box X" simply as "The animal is in box X"). Experiment 2 allowed us to address this possibility directly by contrasting children's interpretation of *may* and *have to*.

EXPERIMENT 2: PRAGMATICS OF EPISTEMIC MODALS

Experiment 2 asked whether children are sensitive to the pragmatic properties of modal terms, especially the scalar and indirectness inferences from the use of epistemic modals. The stimuli and procedure were similar to Experiment 1. However, unlike the earlier study, participants did not evaluate modal statements in isolation but compared two modal statements (or a modal statement and a plain assertion) to each other (cf. Chierchia et al., 2001; Hirst & Weil, 1982; and Introduction). Of interest was whether children could differentiate two true epistemic modal

statements on the basis of their informativeness, preferring a statement with a strong modal (*have to*) over a statement with a weak modal (*may*) when the evidence warranted it. Also of interest was whether children would prioritize plain over epistemically modalized assertions when the speaker had direct visual access to an event (in accordance with the indirectness inference). Finally, any differences between *may* and *have to* could support the conclusion that children are sensitive to individual modal verbs beyond the results of Experiment 1.

Method

Participants.   A total of 16 English-speaking-children (8 female and 8 male, mean age 5;3, ranging from 4;6 to 6;0) and 16 adults (8 female and 8 male) participated. The child participants were recruited from preschools in Newark, Delaware. The adults were undergraduate students at the University of Delaware enrolled in either an introductory psychology or an introductory linguistics course. None of the children or adults had participated in the earlier experiment.

Stimuli and procedure.   At the beginning of the session the experimenter told participants that they would play a game together with two animated characters (Minnie and Donald) and several animals that would appear on a computer. Participants were then presented with 12 animated short stories on a computer screen. The stories were set against a stage identical to that in Experiment 1. At the beginning of each story participants saw an animal standing between two boxes on the stage. Minnie and Donald stood on either side of the stage and watched. Next the stage curtains were lowered and the experimenter told participants that the animal would hide in one of the boxes. During this phase, Minnie and Donald remained in front of the stage curtains and thus could not see the animal and boxes (i.e., they remained visible to participants and had access to the same evidence participants did). After the curtains were lifted to reveal the two boxes, one of the boxes was opened. Depending on the type of modal contrast tested (see below), either the animal was found or the box was empty. At that point, Minnie and Donald offered one statement each about the hiding place of the animal and participants were asked which character gave a better answer. Of interest was whether children would be able to choose the most felicitous of the observers' statements on pragmatic grounds.

There were three types of story illustrating three types of modal contrast. In the first type, the animal was found inside the opened box (e.g., a cow was found to be in the yellow box) and the observers' statements contrasted *may* vs. plain assertion ("The cow may be/is in the yellow box"). In the second story type, the animal was found inside the opened box (e.g., a pig was found to be in the blue box) and the two statements contrasted *have to* vs. plain assertion ("The pig has to be/is in the blue box"). Finally, in the third story type, the opened box contained no animal, so that the animal had to be in the unopened box; both statements targeted the unopened box contrasting *may* vs. *have to* ("The elephant may/has to be in the pink box"). In the first two story types, the modal statements were pragmatically infelicitous because they gave grounds for thinking that the speaker had indirect (inferential) rather than direct evidence for the location of the animal. In the last story type, the weak modal statement was pragmatically infelicitous because it gave grounds for thinking that the speaker had evidence that was simply compatible with (rather than guarantee) the conclusion about the location of the animal. Thus the first two cases are instances of indirectness inferences and the last case is an instance of a scalar inference.

There were four stories for each contrast. The position of the box which served as the hiding place of the object (left-right), the position of the box which was opened (left-right) and the order of presentation of the statements were counterbalanced. Stories were administered in two orders, with one order being the reverse of the other. Minnie and Donald offered an equal number of correct and weak statements each.

Participants were presented with two pre-test trials at the beginning of the experiment. In those trials, participants had to choose the most conversationally appropriate of two true statements in cases that did not involve modality. For instance, participants saw a dog and heard Minnie say, "It is a dog," and Donald say, "It is an animal." Participants were expected to say that Minnie gave a better answer. No feedback was provided. Four children who failed to provide at least one correct response in the pretest trials were replaced. All adults performed at ceiling in the pretest trials.

Results

A preliminary analysis revealed no significant effect of order so we collapse across the two orders in what follows. A 2 (Age: Children. Adults) x 3 (Modal Contrast: *may/plain assertion, have to/plain assertion, may/have to*) ANOVA with repeated measures on the last factor revealed a significant main effect of Age (F $(1, 30) = 14.65$, $p < .005$): children performed correctly (i.e., in a pragmatically appropriate way) 68% of the time and adults 89% of the time. There were no other significant main or interaction effects (see Figure 1).

The proportion of children's correct responses for each of the three modal contrasts was compared to chance levels with single-sample t-tests. Performance on both the *may/have to* contrast (M = 66%, t(15) = 2.6, $p = .001$, 2-tailed) and the *may/plain assertion* contrast (M = 78%, t(15) = 3.92, $p = .001$, 2-tailed) was found to be significantly different from chance but performance on the *have to/plain assertion* contrast was not (M = 61%, t(15) = 1.28, $p = .21$, n.s.).
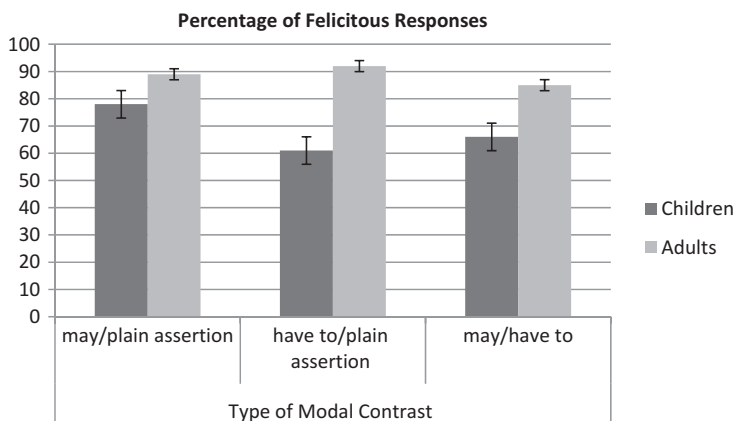

FIGURE 1 Percentage of felicitous (= pragmatically appropriate) responses in children and adults (Experiment 2).

Discussion

The present study asked whether children's comprehension of epistemic modal verbs was sensitive to the pragmatics of epistemic modality (specifically, scalar and indirectness inferences from the use of modals). Results indicate that 4- to 5-year-olds recognized the pragmatic potential of modal verbs in explicitly contrastive contexts: most of the time, children were able to select between modal alternatives (or between modalized and unmodalized assertions) in a way that respected the appropriateness and strength of background evidence available to the speaker. The present results are particularly interesting given that, in nearly identical scenarios in Experiment 1, children (and adults) appeared to be pragmatically oblivious. That is, they overwhelmingly accepted true but underinformative modal statements when more informative ones would also have been true (and relevant). The present data are also important because they show that children (and adults) treat *may* differently from *have to,* a difference that did not emerge in Experiment 1.

The current study is broadly consistent with findings from prior work reporting that children can link modals to the type of commitment a speaker makes to a proposition (Byrnes & Duff, 1989; Hirst & Weil, 1982; Noveck et al., 1996, Exp. 1). Recall that, in these studies, children were presented with a forced-choice task involving two contrasting statements with modal verbs (e.g., "The peanut must be under the box" vs. "The peanut may be under the cup"), or a modal verb and a plain assertion (e.g., "The peanut may be under the box" vs. "The peanut is under the cup"). These studies found that 5-year-olds generally performed well in this task (with some qualifications discussed below). Expanding on these studies, the present data show that children can generally choose the most pragmatically appropriate modal or avoid modals altogether in favor of plain assertions *in accordance with the visual and other background evidence available in the conversational context*.

Nevertheless, here as in Experiment 1, children were clearly not adult-like in their responses. Closer inspection of the three types of modal contrast tested revealed that children's performance in the present study (*may/have to*: M = 66%, *may/plain assertion*: M = 78%, *have to*/plain assertion: M = 61%) was very similar to 5-year-olds' performance in Noveck et al.'s study (1996, Exp. 1; *might/have to*: M = 71%, *might/plain assertion*: M = 84%, *have to*/plain assertion: M = 58%). Our data (and those in Noveck et al.) were also broadly similar to reports on individual modal contrasts in earlier studies (Byrnes & Duff, 1989; Hirst & Weil, 1982), even though they revised upward the age at which the *have to*/plain assertion contrast is reliably understood (in Hirst and Weil's study, 75% of the 5-year-olds passed that contrast). This consistent pattern across studies points to the fact that children's ability to draw pragmatic inferences from the use of epistemic modality is still developing around the age of 5, a point to which we return in the General Discussion.

In the present study we used a judgment task to uncover children's sensitivity to the pragmatics of epistemic modality. In Experiment 3 we introduced a novel method to examine further children's ability to draw pragmatic inferences from the contrastive use of modals.

EXPERIMENT 3: MODAL PRAGMATICS BEYOND JUDGMENT TASKS

In a final study, we probed into children's ability to infer the indirectness of a speaker's evidence from the use of a weak modal statement using an implicit task. Specifically, we tested sensitivity

to indirectness associated with a *may* statement compared with a plain, unmodalized statement in situations where the statements themselves had positive or negative consequences for the child. This method builds on a long line of findings in developmental psychology according to which children are more likely to reveal underlying cognitive competence in tasks that directly engage their interests and goals (e.g., Bever, Mehler, & Epstein, 1968; Gelman & Greeno, 1969).

Method

Participants.   A total of 14 native English-speaking-children (7 female and 7 male, mean age: 4;10, ranging from 4;1 to 5;7) and 20 native English-speaking adults (10 female and 10 male) participated in this study. The children were recruited from preschools in Newark, Delaware. Adults were undergraduate students at the University of Delaware enrolled in an introductory psychology class. None of them had participated in the earlier studies.

Stimuli and procedure.   Participants were told that they would play a game involving two twins. The twins would look alike, dress alike but they would tell children differ-ent things. Each twin had a box that contained a single object. Participants were told that they should listen carefully to what the twins said and then choose one box for them-selves.

There were two types of trial, positive and negative. In the positive trials, the experimenter began by asking children to name something they really liked. If they did not respond, children were encouraged to name one of their favorite foods or toys. After children gave an answer (e.g., "ice cream"), the experimenter displayed a picture of two identical twins (e.g., two twin girls) next to each other on a laptop screen. In front of each twin there was an identical-looking box. The experimenter pointed to the twin on the left and said: "This girl says: *In my box, there is ice cream*". Then the experimenter pointed to the twin on the right and said: "This girl says: *In my box, there may be ice cream*". Children were then asked which box they would choose. In the example above, since ice-cream was something desirable for the child and the modal led to the inference that the speaker lacked direct or trustworthy evidence about whether her box contained ice cream or not, the child was expected to choose the box that belonged to the twin who offered the plain, unmodalized statement. After a box was chosen, the next trial was introduced without feedback.

The procedure for the negative trials was the same except that children in the beginning of each trial were asked to name something they really hated (e.g., "cauliflower"). When the twins' statements were presented (*In my box, there may be cauliflower* vs. *In my box, there is cauliflower*), children were expected to avoid the undesirable items and choose the box that belonged to the twin who had offered the weak modal statement. The procedure for the adult group was exactly the same except that adults were asked to name four things they liked and four things they hated at the beginning of the experiment rather than at the beginning of each trial.

Four positive and four negative trials were administered in a fixed random order. Each trial introduced a new pair of twins. The twin on the left hand side was always the first to speak but the position (left-right) of the twin who offered a plain vs. a weak modal statement was counterbalanced within the stimulus order.
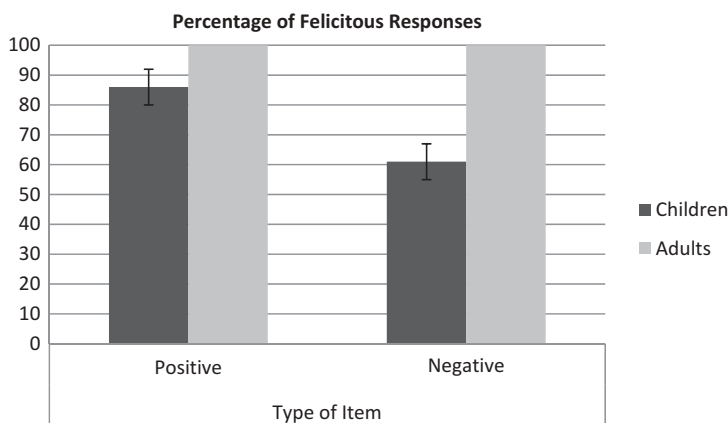
FIGURE 2 Percentage of felicitous (= pragmatically appropriate) responses in children and adults for the positive vs. negative items (Experiment 3).

Results

Results are presented in Figure 2. A 2 (Age: Children vs. Adults) x 2 (Item: Negative vs. Positive) ANOVA with the proportion of correct (i.e., pragmatically appropriate) responses as the dependent variable and Item as a within subjects factor revealed a significant main effect of Age $(F (1, 32) = 156.86, p < .0001)$, with adults being correct 100% of the time and children 74% of the time. The analysis also returned a main effect of Item $(F (1, 32) = 26.35, p < .0001)$, with positive items eliciting correct (*is*) choices 93% of the time and negative items eliciting correct (*may*) choices 81% of the time. Finally, there was an interaction between Age and Item $(F (1, 32) = 26.35, p < .0001)$: for adults, there was no difference in performance between the two types of item $(M = 100\%)$ whereas for children there was a significant difference $(M_{Neg} = 61\%, M_{Pos} = 86\%; t(13) = -4.26, p = .001)$. For both types of item, children's performance was significantly different from chance (Negative: $t(13) = 2.48, p < .05$; Positive: $t(13) = 10.40, p < .0001$).

Discussion

Our results show that young children realize that *may* carries an indirectness inference (and, in this case, reduced speaker commitment) compared with an unmodalized assertion and use this inference to guide their actions; here, that weould be the choice of a desirable object or the avoidance of an undesirable one. These results strengthen and extend the results from Experiment 2, especially with regard to the *may*/plain assertion contrast. Notice that, unlike Experiment 2, children were not asked to explicitly contrast two statements and offer a judgment about their relative appropriateness/felicity. Furthermore, unlike Experiment 2 (and other experiments such as Hirst and Weil, 1982) that required children to consistently pick the stronger of two modal alternatives when comparing their strength, children in the present task needed to alternate between choosing the modal versus the unmodalized statement depending on the statements' (happy or unhappy)

consequences. Given these two unique features of this task, children's above-chance performance offers novel evidence of sensitivity to the pragmatic properties of modals.

An interesting aspect of our data is that, for children, negative items were harder than positive items. One possible explanation for the asymmetry is that it is clear what participants should choose in the positive items (i.e., it is clear that they should choose the box that *does* contain the desirable item over the box that *may* contain the item) but it is perhaps less clear what participants should choose in the negative items: avoiding the box that *does* contain the undesirable item steers choices towards the box that simply *may* contain the unwanted item – but that box could, in fact, contain another, equally undesirable or more undesirable object. When choosing the box that did contain the dispreferred item, children may thus have chosen the "devil they knew" over the devil they did not.

GENERAL DISCUSSION

In this article we examined the scope and potential limitations of children's early knowledge of epistemic modals such as *may* and *have to*, paying special attention to the separate contributions of semantics and pragmatics to modal meaning. Our experiments used novel tasks that asked children to reason about the location of a hidden animal (Experiments 1 and 2) or object (Experiment 3). These tasks were simpler than tasks previously used in the literature to evaluate modal reasoning and the comprehension of modal vocabulary (e.g., Noveck, 2001; Noveck et al., 1996; Piéraut-Le Bonniec, 1980).

Beginning with modal semantics, we found that 4- to 5-year-olds showed some evidence of having acquired aspects of the semantics for the possibility modal *may* and the necessity modal *have to* (Experiment 1). For instance, they reliably provided logical responses to modal utterances about the location of a hidden animal depending on whether the propositions embedded under the modals were compatible with (*may*) or followed from (*have to*) the observational and other evidence available in the experimental context. Nevertheless, 4- to 5-year-olds, unlike adults, were not equally accurate in their semantic judgments of epistemic modals across utterances of different syntactic types. Specifically, children were more likely to accept logically true and reject logically false statements containing the two modals (e.g., "The cow may/has to be in the blue box") than to answer the corresponding *Yes-No* questions correctly (e.g., "Can/does the cow have to be in the blue box?"). This difference appears to be related to children's tendency to respond *Yes* to modal statements that could be construed as guesses about the unobservable location of the animal (this tendency was reduced for questions, which cannot act as guesses).

Furthermore, children, unlike adults, were not equally accurate in their semantic judgments across different modal scenarios (or Story Types). Children were most accurate when faced with situations that straightforwardly gave rise to a necessary conclusion (i.e., situations in which there was a single, unopened box on the stage and thus the animal had to be in that box). Children were somewhat less accurate when there were more steps involved before the necessity of a conclusion could be established (i.e., when one of the two boxes was opened and found empty, and therefore the animal had to be in the other box). Children made the highest number of errors when a conclusion was simply possible but not necessary (i.e., when neither of the boxes on the stage had been opened, and thus the location of the animal was uncertain).

We have proposed that children's errors with uncertain scenarios are not specifically related to the semantics of linguistic modal expressions per se, that is, to children's inability to distinguish that *may* encodes possibility and *have to* necessity (results from Experiment 2 also argue against the possibility that children systematically confuse or ignore *may* and *have to*). Rather children's difficulty seems related to a non-linguistic difficulty that creates a tendency to commit to a possible but not necessary conclusion before decisive evidence is available. This tendency (sometimes referred to as "premature closure"; Acredolo & Horobin, 1987) seems to characterize children's behavior in a variety of reasoning tasks that may or may not involve modal language (Bindra et al., 1980; Byrnes & Overton, 1986; Green, 1979; Horobin & Acredolo, 1989; Klahr & Chen, 2003; Piéraut-Le Bonniec, 1980; Robinson et al., 2006). A similar tendency to underestimate or overlook the uncertainty arising from limited information has been observed in referential communication tasks in which children often seem oblivious to referential ambiguity (e.g., Robinson et al., 2008; Trueswell, Sekerina, Hill, & Logrip, 1999). The difficulty in dealing with indeterminate problems can be overcome by adopting a more complex epistemic stance, whereby two (or more) possibilities can be entertained simultaneously in mind – an ability which may develop well beyond the fifth year (e.g., Acredolo & Horobin, 1987; Bindra et al., 1980; Byrnes & Overton, 1986; Piéraut-Le Bonniec, 1980).

Turning to pragmatic aspects of modals, our data demonstrated strong effects of task on children's ability to calculate inferences from the use of modal expressions. For instance, when asked whether they agreed or not with modal statements in a task which blocked access to modal alternatives, both adults and children massively accepted modal statements that were under-informative with respect to the available evidence (e.g., they agreed with the statement that an animal *might* be in a certain box when the animal *had to* be in that box; Experiment 1). However, when the modal alternatives were presented contrastively, young children (and adults) were capable of selecting the statement that best matched the background evidence available in the conversational context and made the strongest admissible conversational contribution (Experiment 2). Furthermore, young children were capable of linking the use of modals to the speaker's epistemic stance in contrastive situations that did not explicitly involve the evaluation of the felicity of linguistic stimuli (Experiment 3). Even in contrastive environments, however, children's pragmatic performance was not completely adult-like, suggesting continuing development in the pragmatics of modality.

The finding that children's pragmatic sensitivity to modals was context-bound is reminiscent of much prior work that has emphasized the role of task characteristics on the computation of pragmatic inferences (Barner & Bachrach, 2010; Foppolo et al., 2012; Guasti et al., 2005; Huang & Snedeker, 2009; Katsos & Bishop, 2011; Papafragou, 2006b; Papafragou & Musolino, 2003; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007). Our results seem to cohere particularly well with the observation made in past work that children's ability to compute scalar inferences is affected by the accessibility of the stronger scalar alternative (Barner et al., 2011; Chierchia et al., 2001; Papafragou & Skordos, in press). For instance, as mentioned in the Introduction, even though preschoolers failed to consistently reject a weak scalar statement containing disjunction ("Every farmer cleaned a horse or a rabbit") in a story context in which a stronger scalar alternative was true (e.g., where every farmer cleaned *both* a horse *and* a rabbit), they succeeded in picking the stronger/more informative statement when presented with both the strong and the weak scalar alternatives ("Every farmer cleaned a horse or a rabbit" vs. "Every farmer cleaned a horse and a rabbit"; Chierchia et al., 2001). In this and in our own studies, contrastive contexts revealed sensitivity to logical scales and the relative informativeness of scalar terms, which are both key components for the calculation of scalar implicatures.

Despite these similarities, however, there are indications that modals might work differently from other scalar expressions such as quantifiers or disjunctions. For instance, children in Experiment 2 made felicitous choices only 68% of the time when modals (or modals and assertions) were presented contrastively. This success rate is low compared to Chierchia et al.'s study, where 93% of children succeeded in choosing strong (conjunctive) over weak (disjunctive) statements in contrastive contexts (but is consistent with prior studies of modality; e.g., Noveck et al., 1996). Relatedly, adults also made some errors in Experiment 2 (about 10% of the time). Even though this evidence is only suggestive, it raises the possibility that modals may not lead to scalar inferences as readily as other scalar expressions (see also Barner et al., 2011; Papafragou & Musolino, 2003, for evidence of interpretive asymmetries between different types of scalars). A possible explanation for this pattern comes from the fact that weak epistemic modals are sometimes used when the speaker believes a stronger statement to be true but wants to hedge or be polite (Brown & Levinson, 1987, among others). For instance, even if a speaker has definitive evidence that it is raining outside, he/she might say to a stranger, "It may be raining so you may need to bring an umbrella." The role of politeness might make it more difficult for children (and, occasionally, adults) to compute scalar implicatures for modals compared with other expressions.

Taken together, our semantic and pragmatic findings raise several further questions about how children acquire aspects of epistemic modal meanings. First, our data suggest that 4- to 5-year-old children have difficulty with reasoning about indeterminate events but so far the nature of this difficulty has remained unspecified. One possibility is that children's problem with indeterminacy is a result of more general processing limitations such as inability to inhibit a response or difficulty holding onto multiple representations at the same time (e.g., multiple possible locations of the animal in our scenarios; cf. Acredolo & Horobin, 1987; also Ackerman, 1981). Another possibility is that children have stable and specific conceptual limitations in dealing with epistemic uncertainty (cf. Carpendale & Chandler, 1996; Robinson et al., 2006). Our semantic findings (Experiment 1) are compatible with both of these theoretical options. Our pragmatic findings (Experiment 2), however, appear more in line with the processing account since they show that children are sensitive to the difference in informational strength between possibility and necessity modal verbs: if children systematically construed indeterminate situations as being determinate, it is not clear what context would lead them to realize that possibility modals are weaker than necessity modals. Further research is required to address the origin of children's difficulty with indeterminacy and the factors that lead children to overcome this difficulty (see Beck, McColgan, Robinson, & Rowley, 2011; Beck, Robinson, & Freeth, 2008; Klahr & Chen, 2003, for discussion).

Second, several studies have shown that 5-year-old children can compute pragmatic inferences from the use of scalar expressions such as quantifiers even in tasks that were not overtly contrastive, provided that the task goals were clear (see, e.g., Foppolo et al., 2012; Katsos & Bishop, 2011; Papafragou & Musolino, 2003; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007). These studies have also suggested that children's success in deriving scalar inferences may vary depending on properties of individual modal scales (Barner & Bachrach, 2010; Barner et al., 2011; Papafragou, 2006b; Papafragou & Musolino, 2003). It remains to be seen whether young children, upon hearing epistemic modals, can generate and use stronger modal alternatives spontaneously to calculate pragmatic inferences even when those alternatives are not explicitly introduced in the discourse (as in the present studies). It also remains to be seen whether modals might differ in terms of their potential to generate scalar inferences compared to other scalars (perhaps because of the role of politeness), and how exactly scalar inferences relate to other pragmatic (e.g., indirectness) inferences from the use of modals in conversation.

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