Animal but not dog: Children's computation of implicatures for hierarchically organized categories

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Abstract

Children succeed at context-specific *ad hoc* implicatures early, but struggle with generalized scalar implicatures until much later. This developmental trajectory is often explained by children's failure to access relevant alternatives for scalar implicatures. We tested this hypothesis by investigating scalar implicatures involving concrete nouns (superordinate – basic-level – subordinate nouns), termed hierarchical implicatures (HI). To create scenarios where a speaker can felicitously forgo a more informative term, we also manipulated speaker knowledge of different nouns. We found that 4- to 5-year-old children computed HI with superordinates (contrasted with basic-level nouns) only in certain contexts, and did not compute HI with basic-level nouns (contrasted with subordinates). Meanwhile, adults computed HI in both cases. Our findings suggested that difficulties accessing relevant alternatives might not be the main reason for children's late success in computing generalized scalar implicatures. Other factors, such as the ability to represent asymmetric relations between lexical terms, might play a bigger role.

Keywords: implicatures; superordinates; subordinates; pragmatics; language development

Introduction

Language understanding in naturalistic conversations involves inferring both the literal meaning of utterances and the enriched pragmatic meaning, under the assumption that speakers are generally cooperative, informative, and truthful (e.g., Grice, 1975; Clark, 1996; Levinson, 2000). When speakers use less informative expressions when more informative alternatives are possible (e.g., using "some" when they could have said "all"), listeners infer that the stronger expressions do not hold (e.g., interpreting "some" as "some but not all"). While some implicatures draw on knowledge of conventionalized alternatives – lexical items that form ordered scales (e.g., *some/all*), others are *ad hoc* and rely on contextually available alternatives. For example, when a speaker responds to the question "Do you like my friends Alice and Betty?" with "I like Alice!" the listener can infer that they do not like Betty – because otherwise they would have said so. Interestingly, although children struggle to compute conventionalized implicatures involving quantifiers, logical operators, and modals until late in development (e.g., Papafragou & Musolino, 2003; Noveck, 2001), they compute *ad hoc* implicatures by 3.5 years old (Stiller et al., 2015; Horowitz et al., 2018).

There are several factors that may explain why children find *ad hoc* implicatures easier than conventionalized implicatures. First, in the case of *ad hoc* implicatures, it may be easier for children to access relevant alternatives. Previous work has argued that children's difficulties with conventionalized implicatures result from a failure to generate the relevant alternatives (e.g., generating an utterance containing "all" when hearing "some"; Barner et al., 2011; Horowitz et al., 2018). As evidence for this, although children generally fail to compute *some/all* implicatures, they succeed when test trials are preceded by trials that test similar utterances containing "all", thereby making relevant alternatives more accessible (Skordos & Papafragou, 2016). Meanwhile, in tests of *ad hoc* implicature, children appear to access contextually specific alternatives more easily. For example, in a study by Stiller et al. (2015), when children were shown a person with glasses and a hat and another person with just glasses, they readily chose the person with only glasses when asked to find "the man with glasses." On their analysis, when alternatives are defined by contextually available elements like "hat" or "glasses", children access these alternatives more easily than more abstract items like "all", which may not be directly activated by the presence of hats, glasses, etc.

A second factor that may differentiate *ad hoc* and conventionalized implicatures relates to logical entailment. To derive an implicature, children must notice that the spoken utterance is asymmetrically entailed by a stronger alternative. For example, "Mary ate all of the cookies" entails "Mary ate some of the cookies," but not vice versa, and therefore is more informative, and should be used when true. In cases like disjunction, modals, or *some/all* implicatures, this difference depends upon asymmetric relations between individual lexical items like *some* vs. *all*, *or* vs. *and,* or *might* vs. *must*, whereas for *ad hoc* implicature, entailment relations are defined by the number of items that are explicitly mentioned – e.g., "hat and glasses" entails "hat". Given this, it's possible that quickly computing entailment relations between alternatives is easier in the case of *ad hoc* implicatures relative to cases like *some/all*.

While previous studies provide strong evidence that access to alternatives limits children's ability to compute conventionalized implicatures, they leave open whether the rapid computation of entailment relations for scalar terms might also play a role. Complicating this, when previous

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studies have contrasted *ad hoc* and conventionalized implicatures, they have used different lexical items to test each form of implicature – i.e., common nouns for *ad hoc* implicatures, and terms like quantifiers, modals, and logical operators for conventionalized implicatures. In the present study, we sought to address this by testing the role of these different factors via implicatures derived from superordinate nouns, which like *ad hoc* implicatures depend on negating contextually available alternatives, but like *some/all* implicatures require reasoning about lexically specified entailment relations.

In the hierarchical scale "animal" – "dog" – "dalmatian", the basic-level noun "dog" entails the superordinate "animal", and is therefore more informative. Similarly, the subordinate "dalmatian" is more informative than "dog", and entails both "dog" and "animal". Previous work has found that adults use these informative relations to guide their interpretation of common nouns. For example, Choe and Papafragou (2023) found that while adults usually interpreted a novel label as a basic-level noun, they instead interpreted the label as a subordinate noun when they were also presented with a labeled exemplar of a different subordinate kind. Therefore, it is possible that these relations between hierarchically organized common nouns could guide implicature computation as well. To create scenarios where a speaker ostensibly could forgo a more informative term for a less informative one, we manipulated the speaker's knowledge of some terms. For example, take a scenario with a dog and a mouse, and a speaker who only knows the term "dog" and not "mouse." If the speaker refers to an "animal," a listener might infer that they mean the mouse, because they would use the more informative term "dog" if they wanted to refer to the dog. We term this pragmatic inference a hierarchical implicature (HI). As with other implicatures, computing HI requires listeners to identify and negate alternative utterances that are more informative. However, unlike conventionalized implicatures that involve, e.g., quantifiers, HI involves negation of highly familiar common nouns that are contextually accessible. Furthermore, as presented above, the scenarios we used to test HI also involved the speaker providing the relevant alternative utterance in context. As such, children's success in computing HI would suggest that they fail on other conventionalized implicatures due to failing to access relevant alternatives. Meanwhile, children failing to compute HI would suggest that their late success in conventionalized implicatures is because they struggle with computing asymmetric entailment relations.

Experiment 1

We first tested children's ability to compute HI when the speaker's utterance involved a superordinate noun ("animal") and the relevant alternative utterances were contextually available basic-level nouns (e.g., "dog"). This study was preregistered on the Open Science Framework (https://osf.io/es2vn/overview?view_only=65b20fd28d1f498e91760be5fa89ee6b).

Methods

Participants Our sample included 120 children (45F, 75M; M_{age} = 4.82 [4.01; 5.95], SD_{age} = 0.53), recruited and tested at preschools in San Diego, USA and Comox Valley, British Columbia, Canada, and at a museum in San Diego, USA. Sixty adult control participants were also recruited from the UCSD Psychology human subject pool (46F, 11M, 2 Non-binary, 1 Declined to answer; M_{age} = 20.56 [18; 28]; SD_{age} = 1.74). Adult participants were undergraduates who received course credit for their participation. Participants were randomly assigned to three presentation conditions (described below). This study was approved by the UCSD Human Research Protections Program (Protocol #171652).

Design & Procedure Stimuli for the HI task were shown on a PowerPoint presentation. Children were first introduced to a speaker, Penny, and were told that their task was to find Penny's friends. Children first completed two 2-alternative forced choice (2-AFC) familiarization trials, where they were asked to identify Penny's friend between two characters with familiar objects (such as a hat). They were excluded from testing if they could not succeed in either familiarization trial after two attempts.

Participants who succeeded in the familiarization trials then saw eight 2-AFC trials in scenarios like those described in the Introduction. First, two groups of animals were presented. Given that a group of many animals of different kinds might be more prototypical example of "animal" compared to a homogeneous group of animals, or a single animals, we manipulated how the groups of animals were presented in three between-subject conditions (Figure 1A-B-C): Singular (singleton sets), Homogeneous (sets of three animals each, each of the same kind), and Heterogeneous (sets of three animals each, and the competitor set consists of different kinds of animals). In all conditions, Penny first acknowledged that the groups presented were animals ("Look at these animals") to establish that she knew the term "animal." Penny then said that she only knew the name of one group (e.g., "One of them is a dog, but I don't know what the other one is / Some of them are dogs, but I don't know what the other ones are"). If participants named the other animal(s), the experimenter reminded them about Penny's knowledge state ("Remember, Penny doesn't know its / their name(s)"). Then, a character appeared next to each of the animal groups. In four implicature trials, Penny used the less informative superordinate noun to describe her friend ("My friend has an animal"). Children were asked to "point to Penny's friend." We reasoned that if children compute implicatures, then they should point to the character with the animal that Penny did not know the name of (since otherwise she would have used the more informative label that she knew). In four control trials, Penny used the basic-level word for the animal she knew the name of (e.g., "My friend has a dog"). The correct response for control trials was the character with the named animal. Trial orders and the location of the animal groups were pseudo-randomized. Adult controls largely computed the implicature across all three conditions (Singular: M = 0.89, 95% CI [0.80, 0.98]; Homogeneous: M = 0.94, 95% CI [0.83, 1.00]; Heterogeneous: M = 0.95, 95% CI [0.89, 1.00]).

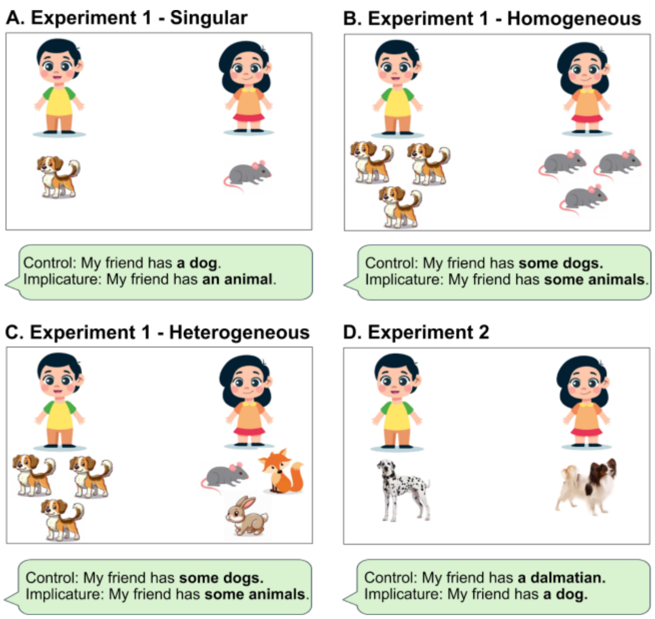

Figure 1: Trials in Experiment 1 (ABC) and Experiment 2 (D). In Experiment 1, the speaker knew the word for "dog" but not the other animals. In Experiment 2, the speaker knew the word for "dalmatian" but not the other dog.

Because computing HI in our task relies on understanding the entailment relation between the superordinate term "animal" and basic-level nouns for specific animals, we measured children's comprehension of the term "animal" in a separate task. Children were shown three pictures, each containing six animals and three distractors. In each picture, they were first asked to identify "all the animals." Each image was then shown again, and participants were then asked to identify specific animals, e.g., "point to all the dogs." Children were given three opportunities to answer each prompt. For each picture, children were considered successful if they answered both the "animals" and the specific animal questions correctly. Participants' animal comprehension score (0-3) was calculated by summing performance over all three pictures. Children in our sample received an average score of 2.44 (SD = 1.01).

Finally, because we manipulated the speaker's knowledge states in our task, we also measured participants' ability to reason about others' mental states as a covariate. Participants completed five Theory-of-Mind (ToM) questions based on the battery used in Wellman and Liu (2004), measuring their ability to reason about other people's desires, beliefs, and knowledge states. Wellman and Liu's criteria were used to compute a ToM score between 0 and 5 points. Children in our sample received an average score of 3.08 (SD = 1.27).

Results

Children performed well on the control trials where they were asked to identify Penny's friend with basic-level nouns for specific animals (e.g., "dog") across all three presentation conditions (M = 0.93, 95% CI [0.90, 0.97], $t(119)$ = 26.42, p < .001). On the implicature trials where they were prompted with the superordinate term "animal," children were significantly more likely than chance to pick the animal that Penny did not know (i.e., computing HI) only in the Heterogeneous condition (M = 0.65, 95% CI [0.55, 0.75], $t(39)$ = 2.93, p = .006). In the Singular and Homogeneous conditions, they chose randomly between the two animals (Singular: M = 0.54, 95% CI [0.44, 0.65], $t(39)$ = 0.87, p = .392; Homogeneous: M = 0.54, 95% CI [0.44, 0.64], $t(39)$ = 0.72, p = .477; Figure 2). A generalized linear mixed model (GLMM) predicting children's performance with Trial Type, Condition and Age (z-scored) as predictors confirmed that participants performed better on control trials compared to implicature trials ($\beta_{implicature}$ = -2.67, 95% CI [-3.12, -2.21], p < .001), and that performance was better among older children (β = 0.29, 95% CI [0.04, 0.55], p = .023). However, Condition was not a significant predictor of performance ($\chi^2(2)$ = 2.89, p = .236). Adding interaction effects between these predictors did not explain significantly more variance in the data in a likelihood ratio test (p = .750). Finally, exploratory GLMMs predicting children's performance on the implicature trials with Condition + Animal Comprehension score and Condition + ToM score as main effects revealed that, while children who scored higher on these tasks were more likely to compute HI across conditions (Animal Comprehension: β = 0.32, 95% CI [0.04, 0.59], p = .024; ToM: β = 0.30, 95% CI [0.00, 0.61], p = .049), scores on these tasks were not significant predictors of HI once age was considered (ps > .05).

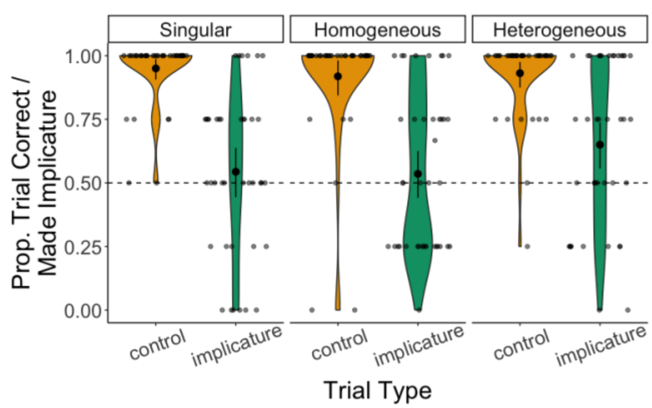

Figure 2: Children's performance on the HI task in Experiment 1

Interim Discussion

Experiment 1 found that 4- to 5-year-old children computed scalar implicatures for utterances involving superordinate terms (HI), but only when shown groups of many animals, and when there were multiple heterogeneous animals in the target set. Further, children's understanding of the term "animal" and their general ability to reason about others' mental states did not predict their ability to compute HI once we controlled for age.

One explanation for children's failure to compute HI when shown singleton sets of animals (the Singular condition) or sets of many animals of the same kind (the Homogeneous condition) is that, at this age, children are not familiar with the term "animal" being used in such contexts. Therefore, presenting the animal sets as one animal or the same kind of animals might result in an infelicity that interferes with their ability to compute HI. However, another possibility is that children at this age might think that the term "animals" only refers to heterogeneous sets of many animals, and not to homogeneous sets of animals or singleton sets. In this case, children's success in the implicature trials in the Heterogeneous condition might be driven by a simple mapping strategy, where only the heterogeneous set of animals – which was also the set that Penny did not know the name of – could be the referent for "animals." One strategy to preclude this possibility is to contrast two heterogeneous sets of animals in the Heterogeneous condition. However, Penny would then need to state that she knew the names of three kinds of animals and not the other three. Children might struggle with remembering and differentiating between animals that Penny knew the names of and those whose names she did not know. Given this, it is difficult to tease apart these two possibilities that could explain why children only computed HI involving superordinate terms in some contexts, making the results in Experiment 1 difficult to interpret.

Fortunately, however, this problem does not apply to the contrast between subordinate nouns like "dalmatian" and less informative basic-level terms like "dog." Given this, in Experiment 2, we tested children with HIs involving basic-level and subordinate nouns. The scenarios in Experiment 2 followed the same logic as Experiment 1 – children were presented with two dogs of different sub-kinds, e.g., a dalmatian and a papillon, and told that the speaker knew that both of them were "dogs" but only knew the word for "dalmatian" and not "papillon". We reasoned that if the speaker asks for the "dog", then a child who computes an implicature should infer that the speaker means to refer to the papillon, because if the speaker had meant to refer to the dalmatian, they would have used the more informative subordinate noun that they knew (i.e., "papillon").

Experiment 2

We tested children's ability to compute HI when the speaker's utterance involved a basic-level noun (e.g., "dog") and the relevant alternative utterances were subordinate nouns (e.g., "dalmatian"). This study was preregistered on the Open Science Framework (https://osf.io/x9qyf/overview?view_only=a1a64613c86f432999cc2823ab6c7ed0).

Methods

Participants Our sample included 64 children (27F, 37M; M_{age} = 4.90 [4.00; 5.98]; SD_{age} = 0.62), recruited and tested at preschools in San Diego, USA and Comox Valley, British Columbia, Canada, and at a museum in San Diego, USA. Thirty-one adult control participants were also recruited from the UCSD Psychology human subject pool (20F, 10M, 1 Declined to answer; M_{age} = 22.23 [18; 41]; SD_{age} = 4.49). Adult participants were undergraduates who received course credit for their participation. No participants had participated in Experiment 1. This study was approved by the UCSD Human Research Protections Program (Protocol #171652).

Design & Procedure The design and procedure mostly followed that of Experiment 1. On each trial in the HI task, participants saw two objects of the same basic-level kind, but different subordinate kinds (Figure 1D). The basic-level kinds used were *dog, bird, flower,* and *hat* (each appeared on a control trial and an implicature trial). After stating the basic-level term for the items, Penny then highlighted each item and stated whether she knew the specific name for that item or not. For the item she knew the name of, she stated its specific name with a subordinate term (e.g., "I know what kind of dog this is. This is a dalmatian."). After that, to confirm that the participant remembered the subordinate term, the experimenter asked the participant to repeat the subordinate term (e.g., "What kind of dog is this?"). If participants could not repeat the term, the experimenter reminded them (e.g., "It's a dalmatian. This is a dalmatian.") For the other item, Penny stated that she did not know its name (e.g., "I don't know what kind of dog this is.") The items were always highlighted from left to right, but the locations of the items Penny knew the name of were pseudo-randomized. In four implicature trials, Penny used the less informative basic-level noun to describe her friend (e.g., "My friend has a dog.") Children succeeded in the implicature trial if they pointed to the character with the item that Penny did not know the name of. In four control trials, Penny used the subordinate term for the item she knew the name of (e.g., "My friend has a dalmatian."). The correct response for the control trials was the character with the named item. The rest of the HI task proceeded similarly to Experiment 1. Adult controls computed HI with subordinate terms (M = 0.71, 95% CI [0.57, 0.85]).

Instead of the animal comprehension task, children received a subordinate naming task to test whether their own knowledge of subordinate terms might interfere with representing and reasoning about the speaker's knowledge states. In this task, children were shown each of the items used in the HI task in blocks of four (corresponding to the four basic-level kinds used), and were asked to name them (e.g., "What kind of dog is this?"). Children were explicitly told that they could respond with "I don't know." Our main interest was in their responses to items that had not been named in the HI task (i.e., items that Penny did not know the name of). We recorded whether participants named the correct subordinate term (though only one child did so on one trial), and whether they gave any name to the item at all. We reasoned that if children thought they had a name for an item, regardless of whether that name was correct, they might find it more difficult to represent Penny's ignorance of the same item because her knowledge state contradicted theirs. Thus, we used whether children attempted to name the item that Penny did not know on each trial in the HI task to predict whether they computed HI on each implicature trial. Finally, children also completed a ToM task as described in Experiment 1 (*M* = 3.17, *SD* = 1.22).

Results

Children performed well on the control trials where they were asked to identify Penny's friend with subordinate nouns for specific items (e.g., "dalmatian"; *M* = 0.93, 95% *CI* [0.88, 0.97], $t(63) = 18.19$, $p < .001$). On the implicature trials where they were prompted with the basic-level term (e.g., "dog"), children picked the item that Penny did not know below chance (*M* = 0.30; *SD* = 0.46; $t(63) = -4.71$; $p < .001$; Figure 3). An exploratory GLMM predicting children's performance with Trial Type and Age (z-scored) as predictors confirmed that participants performed better on control trials compared to implicature trials ($\beta_{implicature} = -4.13$, 95% *CI* [-4.85, -3.41], $p < .001$). Age did not predict performance ($\beta = 0.18$, 95% *CI* [-0.21, 0.57], $p = .357$). Adding interaction effects between these predictors did not explain significantly more variance in the data in a likelihood ratio test ($p = .057$). Finally, exploratory GLMMs revealed that neither attempts to name the 'unknown' item in the subordinate naming task nor ToM scores predicted performance on the implicature trials, even when controlled for age (*p*s > .05).

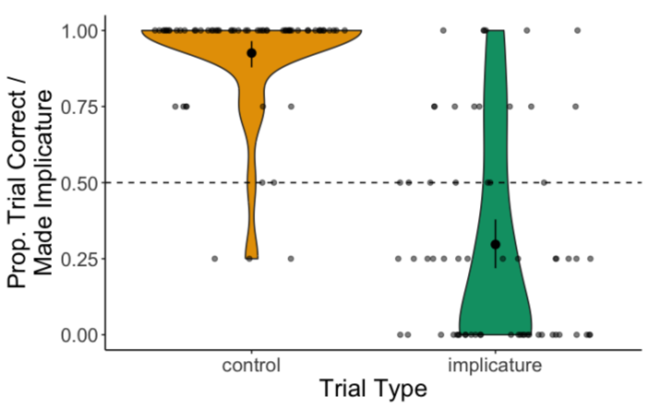

Figure 3: Children's performance on the HI task in Experiment 2

General Discussion

In two studies, we tested children's ability to compute scalar implicatures with hierarchically organized nouns (hierarchical implicatures, or HI). This type of implicature arises based on differences in informativeness between common nouns (e.g., between superordinate vs. basic -level nouns). We found two main results. First, 4- to 5-year-olds computed HI with superordinates (contrasted with basic-level nouns), but only when presented with a choice between selecting a homogeneous group of animals that the speaker knew the name of, and a heterogeneous group of animals that were unknown to the speaker. This leaves unclear whether children were computing HI or merely thought that the heterogeneous group was a more prototypical example of the term "animal." Second, children did not compute HI with basic-level nouns (contrasted with subordinates). Both of these results suggest that children at this age struggled with HI. Children's Theory-of-Mind ability did not relate to variability in computing HI. Together, these results suggest that children's failure in conventionalized implicatures were not due to access of relevant alternatives, because they failed to compute HI despite having access to alternatives that are similar to those in *ad hoc* implicatures, which 4- and 5-year-olds succeed in.

Children's failure to compute HI is interesting given that previous research has pointed to the availability of alternatives as a factor influencing children's implicature computation. Under this analysis, children's early success in *ad hoc* implicatures is due to the relevant alternatives involving common nouns that refer to contextually available elements, which are easier to access. Meanwhile, conventionalized implicatures involve abstract terms like quantifiers, which are more difficult to access and conceal children's pragmatic reasoning ability. HI features common nouns that are familiar to children (particularly in Experiment 1, where the alternative utterances involve basic-level nouns, which should be particularly salient). Additionally, the task we used even mentioned the alternatives explicitly during each trial. Given that the relevant alternatives were similar to those required to compute *ad hoc* implicatures and were contextually accessible, the most likely reason that children failed to compute HI is that they struggled to understand the asymmetric entailment relations between hierarchically organized nouns. For example, basic-level terms asymmetrically entail superordinates, and are therefore more informative. Under this analysis, a child might be able to identify "dog" as an alternative to the utterance "animal," but could not reason about their entailing relations. Then, from this child's perspective, there is no particular reason why a speaker might have said "animal" over "dog," and they could refer to either of the animals presented (resulting in no implicature computation). Supporting this view, research in children's development of hierarchical semantic knowledge has shown that even though children could interpret novel labels as superordinates as early as 3 years old (Fenson et al., 1989; Liu et al., 2001; Waxman & Namy, 1997), children continue to develop knowledge of taxonomic relationships (e.g., the relationship between dog and animal) until 10 years old (Blaye et al., 2006; Lucariello et al., 1992). Relatedly, classic studies investigating children's understanding of the class inclusion logic (e.g., that "dog" logically entails "animal" but not vice versa) also suggest a late emergence (e.g., Inhelder & Piaget, 2013; Winer, 1980). We note that failure in these tasks does not necessarily correspond to failing to represent asymmetric entailment relations between hierarchically organized common nouns. For example, failure in class inclusion tasks can be explained by task pragmatics (Politzer, 2016). Tasks testing taxonomic knowledge usually contrast this with knowledge of thematic relationships (e.g., *dog* and *cat* are thematically related because they are both found in the house). Lower success on such tasks could reflect a categorization bias for thematic relations, rather than a genuine failure to represent taxonomic relations. Regardless, future research could investigate the relationship between taxonomic knowledge and HI success, or use HI as another measure for taxonomic understanding.

Another factor that may have contributed to children's difficulty computing HI was the need to reason about the speaker's knowledge of alternative labels. However, this would be surprising, given that previous evidence for children's early-emerging sensitivity to speaker knowledge and intentions: at 2 years old, children use a speaker's intention to understand their utterances (e.g., Tomasello & Akhtar, 1995), and starting from 3-4 years of age children can use a speaker's knowledge of words to guide their own word learning (e.g., Koenig & Harris, 2005; Sobel & Finiasz, 2020). Furthermore, in our studies, children's ability to reason about others' mental states (measured in the ToM task) did not relate to HI computation. Nevertheless, it is possible that integrating reasoning about speaker knowledge and computing implicatures is costly and difficult for young children at this age. Future research should explore other task designs that reduce demands on children's processing of speaker knowledge to better evaluate children's competency at HI.

While we have presented Experiments 1 and 2 as tests of the same kinds of implicatures, children seemed to struggle more to compute HI in Experiment 2, when they heard utterances with basic-level nouns and had to access alternatives with subordinates. Adult controls showed a similar pattern. One possibility is that some adults and children considered both basic-level and subordinate nouns to be equally informative, and thus did not engage in computing an implicature when they heard a basic-level noun. Another possibility is that adults and children had a weaker representation of the asymmetric entailment relation between basic-level and subordinate nouns compared to between superordinate and basic-level nouns. Regardless, HI provides an opportunity to investigate systematic item differences in conventionalized implicatures and explore why some lexical terms seem to invite more implicatures than others.

In sum, we presented two studies that investigated a new type of conventionalized implicatures called hierarchical implicatures (HI). Despite HI involving familiar and contextually accessible common nouns, we found that children only computed HI for superordinates, and only in some contexts. This suggests that accessibility of relevant alternatives is not the main reason why children begin to compute conventionalized implicatures much later than their success at *ad hoc* implicatures. Failure in conventionalized implicatures might instead result from failing to represent the asymmetric relations between lexical terms.

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