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Preschool children generate quantity inferences from both words and pictures

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ABSTRACT

As children learn to communicate with others, they must develop an understanding of the principles that underlie human communication. Recent evidence suggests that adults expect communicative principles to govern all forms of communication, not just language, but evidence about children's ability to do so is sparse. This study investigated whether preschool children expect both pictures and words to adhere to the communicative principle of quantity using a simple matched paradigm. Children ($N = 293$) aged of 3 to 5 years (52.5% male and 47.5% female; majority White with college-educated mothers) participated. Results show that children as young as 3.5 years can use the communicative principle of quantity to infer meaning across verbal and pictorial alternatives.

Introduction

As children become mature communicators, they learn that mapping linguistic forms to meanings is only one part of conveying information in conversation. To communicate successfully, a child needs to be able to go beyond literal meanings and compute implied aspects of what the speaker intended to convey. Doing so requires access to the principles that govern communication and rational behavior more broadly.

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The development of quantity inferences

One such principle is the *cooperative principle:* participants who engage in a conversation typically have a common goal or purpose in mind and need to cooperate to achieve that goal (Grice, 1975). To that end, speakers are expected to adhere to a set of conversational maxims such as the *maxim of quantity,* which states that speakers should provide as much information as is required by the purposes of the exchange, no more and no less. Taking advantage of these principles, speakers regularly "flout" conversational maxims to communicate additional meanings. Imagine that, during a walk in the woods, Mary's father points to a troop of mushrooms and tells her, "Some of these mushrooms are safe to eat." A reasonable interpretation of this statement is "Some but not all of these mushrooms are safe to eat." Such an interpretation relies on a comparison of what was said with an alternative that the speaker could have used but did not. In the above example, *some* and *all* form a scale ordered in terms of logical strength (Horn, 1972, 1989); "All of these mushrooms are safe to eat" is the stronger alternative because it entails the weaker alternative "Some of these mushrooms are safe to eat" but not vice versa. Given that the *all* statement would have been informative (and relevant) to Mary if true (and because the conversation is cooperative), Mary can infer that the choice of the less informative statement implies that—as far as her father knows—the more informative statement is not true. Therefore, the choice of a *some* statement in a context where it would have been informative (and relevant) to mention *all* is interpreted so as to exclude *all.* This inference is known as a *quantity implicature.* In this case, the quantity implicature depends on a logically ordered quantifier scale (for additional examples of logical term scales, see Horn, 1989; Levinson, 2000).

In other cases, quantity implicatures rely on scales that depend on context-specific information (Hirschberg, 1985). For example, if after encountering brown and orange mushrooms in the woods, Mary hears, "The brown mushrooms are safe to eat," she could infer that the orange ones are not safe to eat. Following the previous logic, given that a statement mentioning both types would have given greater relevant information if true, the choice of the less informative statement gives rise to the inference that the second, unmentioned kind of mushroom is not safe to eat. This subtype of quantity implicatures is called *ad hoc* implicatures (here, the scale consists of the context-dependent alternatives *the brown mushrooms* vs. *the brown and orange mushrooms;* Hirschberg, 1985; Horn, 1972, 1989, 2013). There are currently different theoretical perspectives on whether ad hoc and logical term quantity implicatures are derived similarly or not (see Carston, 1998; Chierchia, 2004, 2006; Chierchia et al., 2009, 2012; Geurts, 2010; Levinson, 2000; Sauerland, 2004, 2012; Sperber & Wilson, 1986; Van Rooij & Schulz, 2004). Regardless of the details, however, most accounts agree that both types of implicature involve a number of steps (Barner et al., 2011; Breheny et al., 2013). Those minimally include computing the basic, literal meaning of the stimulus, generating a set of alternative relevant stimuli that might have been produced (by substitution of scalar alternatives), and later negating the stronger alternatives to establish an informative interpretation of the stimulus.

Adults apply the Maxim of Quantity to compute conversational inferences (Degen & Tanenhaus, 2015; Engelhardt et al., 2006; Frank & Goodman, 2012; Grodner et al., 2010; Huang & Snedeker, 2009a, 2009b; Noveck, 2001), but children aged 4 to 9 years often struggle to do so (Chierchia et al., 2001; Foppolo et al., 2012; Guasti et al., 2005; Huang & Snedeker, 2009b; Papafragou & Musolino, 2003; Noveck, 2001). These findings could be used to argue that implicature computation in children is deficient, delayed, or derailed by processing difficulties. Notice, however, that in many of these studies, children needed to assess utterances offered either by the experimenter (Noveck, 2001; Guasti et al., 2005) or by a less-than-competent speaker (e.g., a "silly puppet"; Katsos & Bishop, 2011; Papafragou & Musolino, 2003) and needed to reject them if they failed to satisfy the Maxim of Quantity. For instance, when asked whether they agreed or disagreed with a statement such as "Some elephants are mammals," children were expected to disagree given that all elephants are mammals (Noveck, 2001). Under these circumstances, children might not have been able to access the stronger alternative *all* (Barner et al., 2011; Papafragou & Tantalou, 2004) or realize that such an alternative was actually relevant given the rest of the conversation (Skordos & Papafragou, 2016). Later developmental studies using alternative, less overt methods that did not rely on utterance evaluations revealed early sensitivity to pragmatic computations (e.g., Foppolo et al., 2012; Katsos & Bishop, 2011; Pouscoulous et al., 2007).

A clear demonstration comes from cases where children need to assign reference—a process that naturally involves monitoring of alternative ways of picking out an object in the world (see also Miller et al., 2005). In a recent study (Kampa & Papafragou, 2020, Experiment 1), 4- and 5-year-olds heard a girl describe one of two boxes in a scene and needed to choose the box she was talking about. From the girl's perspective, one box contained two objects (a spoon and a bowl) and the other contained only one object (a spoon). Both adults and children correctly matched a more informative utterance ("I see a spoon and a bowl") with the two-object box and the less informative utterance ("I see a spoon") with the one-object box. The last critical sentence could, logically, apply to either box but was pragmatically appropriate only for the case where only one object was visible; according to the Maxim of Quantity, if the speaker wanted to choose the box that contained two objects, mentioning only one object (the spoon) would be misleading because it would suggest that the box did not also contain a second object (the bowl). Importantly, participants could see that, in fact, both boxes contained the same two items (e.g., a spoon and a bowl); thus, they could calculate ad hoc inferences even in a context where the speaker's knowledge was different from their own. Other work using a very simple referent selection task (Stiller et al., 2015; see "The current study" section below) found that even younger children successfully compute ad hoc inferences.

Quantity inferences in nonlinguistic communication

Grice (1975) and others (e.g., Sperber & Wilson, 1986) proposed that communicative principles stem from the assumption that others will behave rationally and therefore such principles should apply to all forms of purposive exchanges that rely on expectations of rational behavior. There is evidence that even young children can interpret a variety of actions and nonverbal cues as intentional and communicative (see Grigoroglou & Papafragou, 2017, for a review). However, little work to date has addressed whether and how children derive pragmatic inferences such as quantity implicatures from communicative acts involving nonlinguistic symbols (including, but not limited to, gestures, pictures, maps, road signs, blueprints, and drawings).[1]

Pictures are a particularly interesting type of nonlinguistic symbol to consider as a counterpart to words. Children can use pictures communicatively early on; when an experimenter points at a picture of the location of a toy, 2.5-year-old children can use that picture to find the toy in a real room (DeLoache, 1987, 1991; Marzolf & DeLoache, 1994). Children are also sensitive to the features that make a picture informative; three-year-olds understand that a highly detailed drawing is more useful than a minimally detailed drawing for someone who wants to learn what a house looks like, and a more prototypical, less detailed drawing is better than a less prototypical, more detailed drawing (Allen et al., 2010; see also Fan et al., 2023; Huey et al., 2022). In general, children develop an understanding of dual representation—the fact that a picture, by virtue of being a symbol, is both a physical entity in itself and an abstract representation of something else (DeLoache, 2000; Uttal et al., 2009). However, understanding pictorial symbols pragmatically requires going beyond their literal representational meaning and inferring what they are meant to communicate. Do children apply pragmatic (e.g., quantity) principles to the use of pictures to derive nonliteral meanings, as classic pragmatic theories predict?

Recent studies suggest that, unlike adults, 4- and even 5-year-old children show limited success in applying the quantity maxim to communicative acts involving pictures (Kampa & Papafragou, 2020, 2023; Papafragou et al., 2018; cf. Tieu et al., 2019). Recall that, in a study by Kampa and Papafragou (2020, Experiment 1), 4-year-olds, 5-year-olds, and adults overwhelmingly used the informativeness of a girl's statement about the contents of a box ("I see a spoon" or "I see a spoon and a bowl") to identify which of two boxes in the scene she was talking about, even though they themselves could see that both boxes had identical contents (a spoon and a bowl). But in a closely matched pictorial version

[1] Much prior work on quantity implicatures has presented children with a verbal communicative act (e.g., *some* or *all* statements) that needed to be evaluated, verified, or otherwise processed in the context of pictures or visual stories (Chierchia et al., 2001; Foppolo et al., 2012; Guasti et al., 2005; Huang & Snedeker, 2009b; Katsos & Bishop, 2011; Miller et al., 2005; Papafragou & Musolino, 2003). Even though this work involved pictures, it did not include a pictorial communicative act and hence does not bear on the question of whether Gricean maxims such as quantity extend to nonlinguistic communication.

of the same study (Experiment 3), the results were strikingly different. In that version, participants saw a line drawing of the two objects (the spoon and the bowl) and heard the girl say "I see this" while a red circle was slowly drawn around one or both of the objects. Adults successfully used these pictorial cues to identify the correct box; children, however, succeeded only with the more informative (two-object) cue but not with the less informative (one-object) cue that relied on a quantity inference. Later versions of the paradigm with very schematic single-object and two-object drawings showed that 5-year-olds—but not younger children—could use both kinds of drawings to pick out the box that the speaker intended to refer to (Kampa & Papafragou, 2023).

How should we interpret children's selective difficulty? One possibility is that, even though adults broadly apply the quantity maxim to different ostensive stimuli in accordance with classic pragmatic theories (Grice, 1975; Sperber & Wilson, 1986), children—especially those under 5 years of age—are unable to do so. However, given the work just reviewed (Allen et al., 2010; cf. Fan et al., 2023; Huey et al., 2022), it is unlikely that children fail to understand that pictures can be more or less informative. Furthermore, recent work (Sullivan et al., 2022) argued that other aspects of the Gricean system apply to both words and nonverbal stimuli.

An alternative possibility is that, even though omissions from pictorial stimuli can function similarly to omissions from linguistic utterances and can be interpreted in terms of quantity, children may have lacked practice in interpreting pictures (and lack of information in pictures) this way (Kampa & Papafragou, 2020, 2023). Specifically, in the above studies, understanding less informative drawings pragmatically (e.g., a picture of a spoon) involved mentally generating and negating relevant more informative drawings that the communicator could have produced but did not (e.g., a picture of a spoon and a bowl). Even though the process of accessing relevant alternatives was in principle identical for both verbal and pictorial stimuli, in practice children were more used to evaluating alternative ways of referring to an object linguistically as opposed to pictorially.[2] In addition, computing and evaluating pictorial alternatives needed to take into account the perspective of one's interlocutor. A less informative (single-object) drawing was appropriate when the communicator had limited knowledge. However, assessing and comparing drawings from the perspective of one's communicative partner was less likely to be familiar to children compared with assessing what a speaker said given the speaker's mental state (on the latter, see Clark, 1987).

Currently, additional experiments are warranted to examine children's ability to engage in quantity inference when the communicative act itself involves linguistic versus nonlinguistic stimuli (and hence invokes linguistic versus nonlinguistic alternatives to these stimuli). These experiments would be particularly useful if they compared both types of stimuli across multiple age groups. In what follows, we pursued this line of work. A positive demonstration of quantity implicatures in both the verbal and nonverbal domains, especially for young learners, would add to evidence for early pragmatic sophistication; furthermore, it would offer strong support for a core but little-tested claim of classic pragmatic theories according to which the ability to apply pragmatic reasoning to compute intended meanings generalizes beyond language to other communicative acts (Grice, 1975; Sperber & Wilson, 1986). Finally, by comparing the application of the same pragmatic principle across domains and ages, we gain an important test of whether general pragmatic principles are applied along similar timelines across stimulus types.

The current study

This study asked whether children apply pragmatic principles, specifically the Maxim of Quantity, to the interpretation of both linguistic and nonlinguistic (pictorial) symbols. It adopted a very simple paradigm (Stiller et al., 2015) that has been used to show early success with quantity (ad hoc) implicatures. In that study, 3- to 5-year-olds engaged in a straightforward referential game with a single communicative partner (the experimenter) who shared full visual access to the referential scene with the participants. Children were exposed to three referents (e.g., a person with a hat and glasses, a per-

[2] This view helps to explain why more schematic drawings facilitated pragmatic computations (Kampa & Papafragou, 2023): because more abstract pictures are more likely to be interpreted symbolically (Uttal et al., 2009), their role and (in)appropriateness as a referential tool became clearer.

son with only a hat, and a person with neither). In critical trials, the experimenter offered a sentence with a single identifying feature ("My friend has glasses"). Beginning with older 3-year-olds, children could use the informativeness of the description to pick out the intended (one-feature) character. The current sample tested 3-, 4-, and 5-year-old children on both verbal and pictorial stimuli; the youngest age group is of particular interest because older (but not younger) 3-year-olds were able to calculate pragmatic inferences in Stiller et al. (2015).

In the current design, children were presented with images of three objects: a one-feature object (e.g., a doll with a bow), a two-feature object (an identical doll with a bow and a purse), and a distractor object (an identical but plain doll). Children were assigned to one of three conditions. In the Linguistic condition, the experimenter said, "My doll has a bow" (cf. Stiller et al., 2015). In a novel Picture condition, the experimenter said, "My doll has this" while showing a card with a picture of a bow on it. In both conditions, children were then asked, "Which one is my doll?" Finally, in a Control condition, children were simply asked to pick the experimenter's doll without any prior cues (as in Stiller et al., 2015).

The rationale for the design is as follows. In the Linguistic condition, following the cooperative principle, if the experimenter had intended to indicate the two-feature object, it would have been more informative to mention both features (e.g., "My doll has a bow and a purse") or even just the disambiguating feature (the purse). Because the experimenter did not do that, the listener would be justified in inferring that the object had only the mentioned feature (a bow) and no other feature. Thus, a successful pragmatic listener would be expected to choose the one-feature referent. Similarly, in the Picture condition, if a cooperative pictorial communicator had intended to indicate the two-feature object, it would have been more informative to present a picture of both features (i.e., both the bow and the purse) or even just the disambiguating feature (the purse). A pragmatic responder should interpret the choice of presenting only a single feature as excluding other objects having this and additional features. Thus, in both conditions, even though either the one- or two-feature doll was a logically correct choice (because both dolls had a bow), only the one-feature doll would be the correct pragmatic choice. Furthermore, in the Control condition, in the absence of specific information, this one-feature referent should be less likely to be picked (thereby removing the possibility of baseline differences in the salience of one referential choice over others).

Note that the prompt in the Picture condition does include linguistic material ("My [X] has this"). However, as prior work (Kampa & Papafragou, 2020, 2023) has shown, this fact does not guarantee that the derivation of an inference from the use of a picture will proceed as with a regular sentence example. This is because the critical inference relies on applying pragmatic principles to a pictorial ad hoc scale (a picture of a bow vs. an alternative potential picture of a bow and a purse) because it involves comparing the stimulus with another possible ostensive stimulus that could have been produced but was not. There are other cases in the literature where words and pictures are not equivalent: Vales and Smith (2018) reported that, in a visual search task, the name of the target alone facilitated 3-year-olds' target identification more than an image of the to-be-found object.

Our current paradigm maintained the logic of prior referential tasks (e.g., Kampa & Papafragou, 2020, 2023) but streamlined the ostensive use of words versus pictures as a cue for referent selection to provide a better test of the domain of application of pragmatic principles. Furthermore, this work allowed for a direct comparison of the developmental timeline for deriving pragmatic inferences from linguistic versus nonlinguistic scales.

Method

Participants

Data were provided from 293 children, including 126 3-year-olds (M_{age} = 3;5 [years;months], range = 3;0–3;11), 84 4-year-olds (M_{age} = 4;4, range = 4;0–4;11), and 83 5-year-olds (M_{age} = 5;4, range = 5;0–6;0). The 3-year-old group was oversampled because prior work using the same method (Stiller et al., 2015) had indicated considerable development within this cohort, and an additional goal of this study was to conduct more detailed comparisons between younger and older children in this age group. An additional 4 children were tested but excluded from analysis due to low accuracy on filler trials. Children were recruited from the Delaware Children's Museum in Wilmington, DE or the Early Learning Center in Newark, DE and were given a sticker or piece of candy for participating.

Demographic data collected from participants indicated that the majority of children in our sample were White (82.6% White, 7.8% multiracial, 7.0% Black, and 2.6% Asian American), with 6.2% of our participants identifying as Hispanic. The majority of children in our sample had college-educated mothers (highest level of degree completed: 13.4% high school, 7.5% some college, 1.5% associate's degree, 31.3% bachelor's degree, 37.3% master's degree, 3.0% professional degree beyond bachelor's degree, 6.0% doctoral degree). Participants were 52.5% male and 47.5% female. All participants were monolingual speakers of English.

Materials and procedure

The task used was adapted from Stiller et al. (2015). Children were told that they were going to play a game with the experimenter. They were presented with a trio of images on a printed page placed in a laminated sleeve in a binder (Fig. 1). All three images contained the same base object (e.g., a doll, as in Fig. 1) that varied in terms of two further features (in this case, a bow and a purse). Thus, each display contained a distractor image (which had no features—here, a plain doll), a one-feature image (a doll with a bow), and a two-feature image (a doll with a bow and a purse). Children needed to identify one of the three objects on the card on the basis of what they heard from the experimenter.

Participants were randomly assigned to one of three conditions: Linguistic (n = 109), Picture (n = 110), or Control (n = 74). (Three-year-olds were oversampled in the Linguistic and Picture conditions only because the Control condition was not as important theoretically.) The Linguistic and Control conditions were modeled after Stiller et al. (2015). In the Linguistic condition, children were presented with the trio of images and told "My [X] is/has [Y]" (e.g., "My doll has a bow"). They were then asked "Which one is my [X]?" ("Which one is my doll?"). The Y feature (e.g., a bow) was always shared by two of the referents (the one-feature and two-feature referents). The Picture condition followed the same logic as the Linguistic condition, but children were instead shown a card containing a picture of the Y feature for referent identification. For example, in place of hearing "My doll has a bow," children were told "My doll has this" while being shown a card with a picture of a bow on it (Fig. 1). Lastly, children in the Control condition were given no information about the images and were simply asked to pick which object belonged to the experimenter. This condition served as a baseline for children's selection preferences in the absence of any cues.

For each condition, there were 8 test trials (that required pragmatic inference), as described above, and 4 filler trials (that were unambiguous). For the filler trials, each of the three pictures presented the same base object but with a unique feature (e.g., three plates, each with different contents: pizza, broccoli, or hot dog). Thus, the clues pointed to an unambiguous selection in both the Linguistic condition (e.g., "My plate has pizza. Which one is my plate?") and the Picture condition (e.g., "My plate has this [picture of a pizza]. Which one is my plate?"). The number of both test and filler trials was doubled from Stiller et al. (2015); of the 12 trials, images for 6 of the trials were designed from the stimuli list given by Stiller and colleagues, and images for the other 6 trials were created following the same parameters (a no-feature, one-feature, and two-feature referent that could be described by the sentence "My [X] has [Y]"; see online supplementary material for a full list). The placement of the target one-feature image (either left, center, or right on the page) and the selection of the feature to be used for disambiguation (e.g., bow or purse) in these images were counterbalanced among participants, resulting in six unique arrangements of trials.

Results

Data for this experiment are available at the Open Science Framework (https://osf.io/qkxd4). Children who had an accuracy score of 25% or lower on filler trials were excluded from analysis (n = 4). Filler accuracy was consistent across test conditions ($M_{Accuracy}$ = 90.4%) and thus is not reported in detail. Results from test trials are presented in Fig. 2; for easy visualization, children are divided into

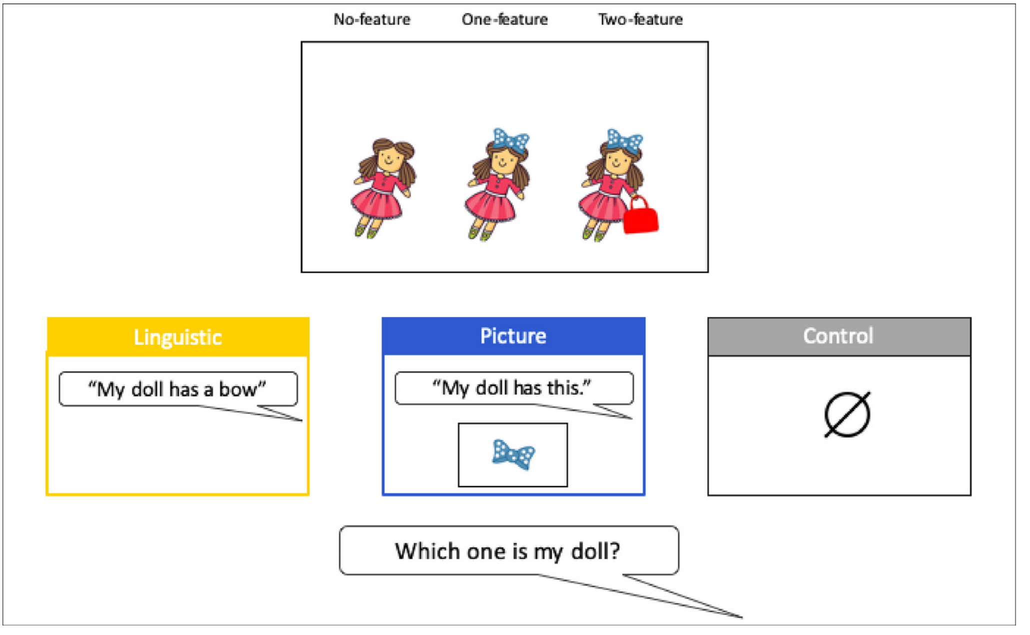

Fig. 1. Sample test trial across the Linguistic, Picture, and Control conditions.

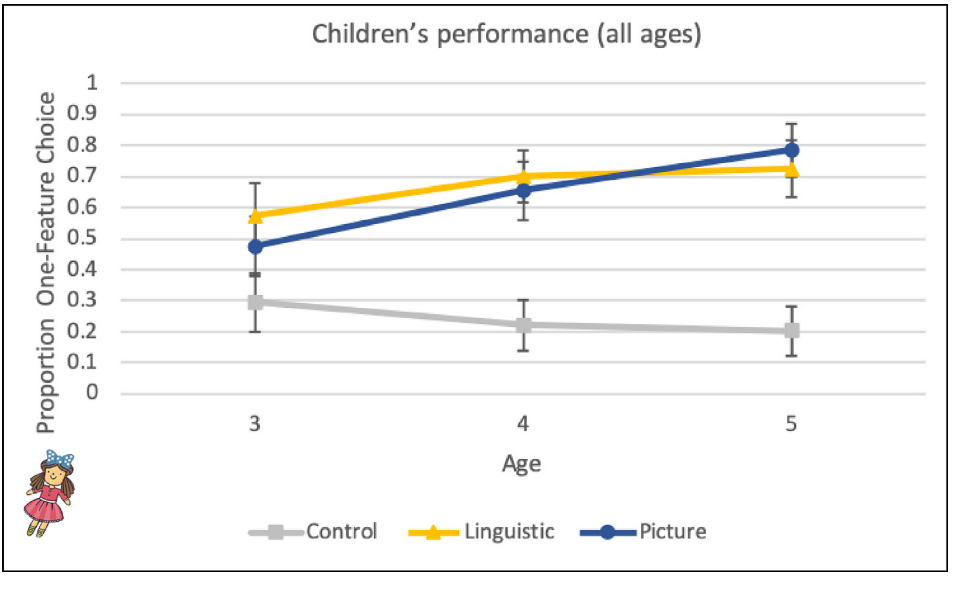

Fig. 2. Proportions of pragmatic (one-feature) choices on test trials in the Control, Linguistic, and Picture conditions. Participants are divided into 1-year age bins for ease of visualization. The *y*-axis indicates the proportion at which each group selected the target one-feature referent.

Table 1
Mean proportions and standard errors of pragmatic (one-feature) referent choices on test trials by age group and condition.

	Linguistic			Picture			Control		
Age	Mean	*SE*	*n*	Mean	*SE*	*n*	Mean	*SE*	*n*
Younger 3-year-olds	.536	.100	25	.428	.097	26	.304	.133	12
Older 3-year-olds	.606	.096	26	.519	.098	26	.273	.135	11
4-year-olds	.699	.084	30	.655	.088	29	.220	.083	25
5-year-olds	.728	.084	28	.784	.077	29	.202	.079	26

age bins for each year in each condition (Fig. 2). Performance means and standard errors, as well as number of children within each age bin, are given in Table 1.

Pragmatic responding across conditions

In analyzing the results, the first goal was to compare children's pragmatic performance across conditions. The analysis began by comparing the rate at which participants responded pragmatically on test trials (i.e., selected the one-feature referent) across the Linguistic, Picture, and Control conditions. The data were analyzed using multilevel logistic mixed effects modeling. All models were fit using the *glmer* function of the "lme4" package (Bates, 2005; Bates et al., 2011, 2015; Bates & Sarkar, 2007) in the R Project for Statistical Computing (R Development Core Team, 2012). Interactions that did not significantly improve model fit were removed from the model. Pragmatic responding (i.e., proportion of selecting the one-feature referent) was analyzed with a model that included condition (Linguistic, Picture, or Control) and age (continuous) as fixed predictors, and participants and items as random intercepts. Table 2 presents the parameter estimates for the multilevel model.

Our model revealed an effect of age, an effect of condition, and a significant interaction between the two. Unsurprisingly, older children chose the target (one-feature) referent at a higher rate than younger children. For condition, further analyses revealed that children in the Linguistic and Picture conditions chose the target referent at a rate significantly different from children in the Control condition (Linguistic/Control: $p < .001$; Picture/Control: $p < .05$). There were no significant differences in pragmatic response rates between children in the Linguistic and Picture conditions ($p = .064$). To explore the interaction between condition and age, the next step was to look at performance within each of the three discrete age groups (3-, 4-, and 5-year-olds). The 3-year-olds in the Linguistic and Picture conditions already chose the one-feature referent at a significantly different rate from those in the Control condition (Linguistic/Control: $p < .001$; Picture/Control: $p < .001$); however, this difference grew larger in 4- and 5-year-olds. In addition, 3-year-olds chose the one-feature referent at a significantly different rate in the Linguistic condition compared with the Picture condition (Linguistic/Picture: $p = .022$), although 4-year-olds (Lingustic/Picture: $p = .389$) and 5-year-olds (Linguistic/Picture: $p = .368$) did not.

Pragmatic versus logical responding to words and pictures

Given that both the one-feature and two-feature referents were logically acceptable choices for test trials, one goal was to compare the rates at which young children chose the pragmatic (one-feature) referent over the nonpragmatic (two-feature) referent on these trials for the Linguistic and Picture conditions. For both conditions, the proportion of selecting a given referent was analyzed with a model that included referent (no-feature, one-feature, or two-feature) and age (continuous) as fixed predictors and participants and items as random intercepts. The fixed effect of referent was coded with two simple contrasts comparing the incorrect no-feature referent with the two logically possible referents (c1: −.66,.33,.33) and comparing the pragmatic one-feature referent with the nonpragmatic two-feature referent (c2: 0, −.5,.5). The proportion of the selection of each referent by condition and age group is presented in Table 3. Given that 3-year-olds were of particular interest (and were sampled

Table 2
Parameter estimates for the proportions of pragmatic (one-feature) referent choices on test trials.

Effect	Estimate	*SE*	*z*
Intercept	−1.397	0.350	−3.994***
Condition (Control vs. Linguistic and Picture)	−2.397	0.795	−3.015**
Condition (Linguistic vs. Picture)	−1.397	0.754	−1.853
Age (continuous)	0.332	0.079	4.211***
Condition (Linguistic vs. Control)	1.719	0.874	1.967*
Condition (Picture vs. Control)	3.071	0.871	3.527***
Condition × Age	1.0125	0.181	5.595***
Condition (Linguistic vs. Picture) × Age	0.297	0.178	1.663

* $p < .05$
** $p < .01$
*** $p < .001$

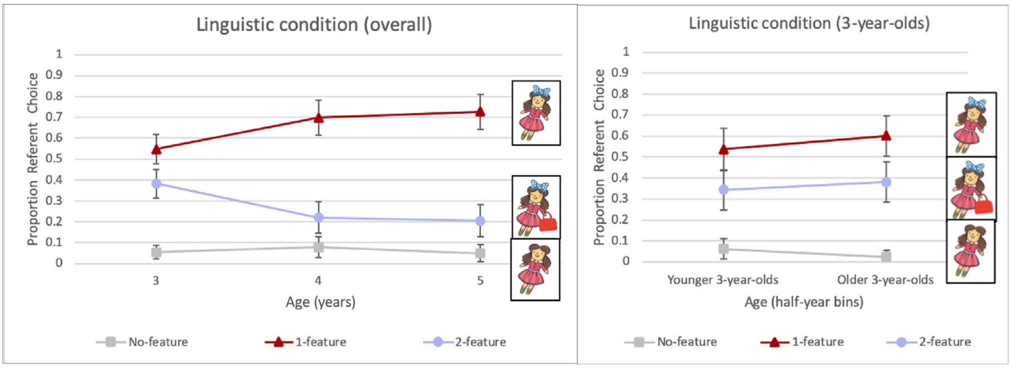

Fig. 3. Proportions of selecting each of the three referents during test trials for the Linguistic condition. Each type of referent (1-feature, 2-feature, and no-feature) is schematically represented by a sample stimulus. The pragmatically correct referent is the 1-feature choice (in the example, doll with bow only).

Table 3
Proportions of one-feature, two-feature, and no-feature referent choices on test trials by condition and age group.

	Linguistic			Picture		
Age	1F	2F	NoF	1F	2F	NoF
Younger 3-year-olds	.536	.344	.063	.428	.438	.082
Older 3-year-olds	.606	.380	.024	.519	.407	.069
4-year-olds	.699	.221	.079	.655	.332	.022
5-year-olds	.728	.205	.049	.784	.164	.056

Note. 1F, one-feature; 2F, two-feature; NoF, no-feature.

more intensively), we divided the 3-year-olds in the Linguistic and Picture conditions into two half-year age bins: younger 3-year-olds (3;0–3;5) and older 3-year-olds (3;6–3;11) to further explore development within this year.

The proportions at which children selected the no-feature referent, one-feature referent, and two-feature referent in the Linguistic and Picture conditions are displayed in Fig. 3. Parameter estimates for referent selection in the Linguistic condition are displayed in Table 4. Our model revealed an effect of

Table 4
Parameter estimates for referent selections on test trials in the Linguistic condition.

Effect	Estimate	*SE*	*z*
Intercept	−0.903	0.344	−2.622**
Referent (no-feature vs. one-feature and two-feature)	2.128	0.893	2.384*
Referent (one-feature vs. two-feature)	2.855	0.617	4.625***
Age (continuous)	−0.031	0.079	−0.391
Referent × Age	0.113	0.205	0.551
Referent (one-feature vs. two-feature) × Age	−1.029	0.144	−7.167***

* $p < .05$
** $p < .01$
*** $p < .001$

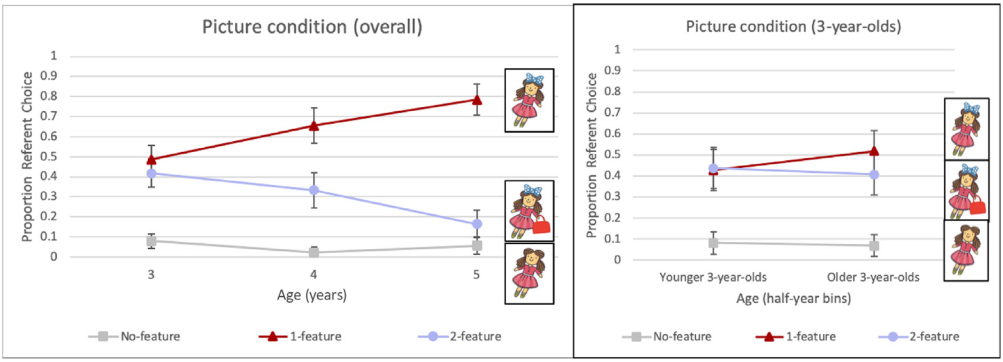

Fig. 4. Proportions of selecting each of the three referents during test trials for the Picture condition. Each type of referent (1-feature, 2-feature, and no-feature) is schematically represented by a sample stimulus. The pragmatically correct referent is the 1-feature choice (in the example, doll with bow only).

Table 5
Parameter estimates for referent selections on test trials in the Picture condition.

Effect	Estimate	*SE*	*z*
Intercept	−0.891	0.355	−2.506*
Referent (no-feature vs. one-feature and two-feature)	1.459	0.932	1.565
Referent (one-feature vs. two-feature)	4.577	0.617	7.414***
Age (continuous)	−0.393	0.084	−0.466
Referent × Age	0.305	0.221	1.381
Referent (one-feature vs. two-feature) × Age	−1.386	0.147	−9.443***

* $p < .05$
*** $p < .001$

referent (one-feature vs. two-feature) and a significant interaction between referent (one-feature vs. two-feature) and age. Overall, children selected the pragmatic one-feature referent at a significantly different rate from the nonpragmatic two-feature referent ($p < .001$). As indicated by the interaction, children chose the one-feature referent over the two-feature referent at a progressively greater rate over the course of development ($p < .001$). The youngest age group in which children chose the one-feature referent at a significantly different rate from the two-feature referent was the younger 3-year-olds ($\beta = -0.86$, $z = -2.67$, $p < .008$).

The proportions at which children selected the no-feature referent, one-feature referent, and two-feature referent in the Picture condition are displayed in Fig. 4. Parameter estimates for referent selection in the Picture condition are displayed in Table 5. Our model revealed an effect of referent (one-feature vs. two-feature) and a significant interaction between referent (one-feature vs. two-feature) and age. Children selected the pragmatic one-feature referent at a significantly different rate from the two-feature referent (p <.001). As indicated by the interaction, children chose the one-feature referent over the two-feature referent at a progressively greater rate through the course of development (p <.001). The youngest age group in which children chose the one-feature referent at a significantly different rate from the two-feature referent was the older 3-year-olds ($\beta = -0.45$, $z = -2.31$, p =.02).

Discussion

Beyond words: Quantity inferences from nonlinguistic symbols

Participants in a conversation are expected to adhere to certain conversational principles (Grice, 1975). For example, communicators are expected to provide as much information as is required by the purpose of the exchange. Classic theories of communication (Grice, 1975; see also Sperber & Wilson, 1986) have proposed that these principles govern all forms of purposive exchanges as a consequence of expecting others to behave rationally. Recent attempts to test whether communicative principles, specifically the Maxim of Quantity, apply to nonlinguistic symbols such as pictures found an asymmetry, with 4- and 5-year-olds struggling to apply these principles to pictures despite success in a previous matched linguistic task (Kampa & Papafragou, 2020). Even when 5-year-olds succeeded, their success was sensitive to properties of the pictorial stimuli (Kampa & Papafragou, 2023). Other studies, however, have found evidence that preschoolers interpret verbal and nonverbal stimuli similarly in other areas of pragmatic reasoning (Sullivan et al., 2022).

The current study used a simple paradigm (adapted from Stiller et al., 2015) to revisit the question of whether children apply pragmatic principles—specifically, the Maxim of Quantity—to pictures as well as words. In this referent selection task, participants were presented with three possible referents: one with no identifying features, one with a single feature, and one with two features. Participants were asked to select which one was the experimenter's doll based on information presented with either a picture of a shared feature (e.g., a bow) or a sentence describing that feature (''My doll has a bow"). Of interest was whether participants would interpret a less informative picture as excluding a more informative picture (and, e.g., take a picture of a bow to imply that the doll had only a bow and not a bow and a purse).

These data make three novel contributions to the field of pragmatics. First, our results go beyond previous claims that children as young as 3.5 years are able to derive quantity inferences from linguistic ad hoc scales (Stiller et al., 2015) by providing evidence of the presence of such inferences in even younger 3-year-olds (3;0–3;5). At this time, the success of young 3-year-olds in the current study offers the earliest available evidence of sensitivity to quantity inferences. It is likely that doubling the number of trials compared with Stiller et al.'s (2015) task contributed a more stable picture of young 3-year-olds' abilities even within an otherwise very similar paradigm. These findings support previous claims in the literature according to which children display early pragmatic sensitivity to linguistic input (Kampa & Papafragou, 2020; Katsos & Bishop, 2011; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007; Stiller et al., 2015) and argue against the possibility that implicature computation in children is deficient, delayed, or derailed by processing difficulties. Unlike many prior tasks that measured quantity implicatures via explicit judgments of the truth or felicity of sentences, the current method relied on referent resolution, a ubiquitous and natural process throughout children's everyday life. In addition, this task (along with its predecessors; Kampa & Papafragou, 2020; Stiller et al., 2015) requires a single correct response, a feature that may also have encouraged children to consider alternative ways of picking out the different possible candidate referents in the scene.

Second, our data provide evidence that children as young as 3.5 years use quantity principles to reason over scalar alternatives triggered by pictures as well as words. Our results offer one of the first empirical pieces of support for models of inferential pragmatics that take the ability to use communicative principles to apply to several varieties of intentional stimuli as opposed to being specific to language (Grice, 1975; Sperber & Wilson, 1986; cf. Sullivan et al., 2022). Our data significantly lower estimates from recent work that used more complex reference resolution tasks to probe quantity implicatures from nonlinguistic stimuli (Kampa & Papafragou, 2020, 2023). Furthermore, the current findings expand research on children's dual representation theory, the understanding that a symbol is both a physical entity in itself and an abstract representation of something else (DeLoache, 2000; Uttal et al., 2009). In our task, children not only interpreted pictures symbolically but also compared them with other pictures that the communicator could have used instead and drew inferences about what the communicator meant. Thus, going beyond earlier work on dual representation, this study shows that even preschoolers understand that pictures carry information not only explicitly by virtue of what they contain but also implicitly by virtue of what they omit.

Third, our data reveal overall similar trajectories for quantity inferences across linguistic and pictorial scalar alternatives. Even though there is considerable development throughout the sampled ages, there is no reason to doubt that the same mechanisms underlie pragmatic inference across verbal and pictorial alternatives. Nevertheless, this study found some differences between deriving quantity inferences from words as compared with pictures in the earliest stage of development; there was a significant difference in choosing the (pragmatic) one-feature referent between the Linguistic and Picture conditions in 3-year-olds. In addition, in the Linguistic condition, the youngest age group to choose the target pragmatic referent at a significantly different rate from the logical response was the younger 3-year-old group, whereas in the Picture condition the earliest age group was the older 3-year-old group.

These early differences echo previous findings suggesting that reasoning about pictorial alternatives as compared with linguistic alternatives can be more difficult (Kampa & Papafragou, 2020, 2023). After all, even young children routinely use lexical contrast when interpreting their input; for instance, during word learning, children often consider a novel word in the context of other known words that the speaker could have produced (Clark, 1987; Markman, 1994). However, the steps for generating and comparing alternative relevant pictures that could serve as communicative cues might not be as straightforward; pictures, unlike words, do not have a unique semantic content, and the process of setting up pictorial scales may need strong contextual support. Even so, by 4 years of age the differences between inferences derived from linguistic alternatives and those derived from pictorial alternatives disappeared.

Two observations are in order about the Picture condition. This task used pictorial stimuli that were identical to their symbolic referent. If the similarity between the two pictures was reduced or the pictorial stimuli were made more interesting as physical entities, then it is likely that this task would have proven to be more challenging to young children who are still developing a complete understanding of dual representation. Moreover, as mentioned already, the Picture condition still involved some language (“My [X] has this”), even though it relied on a pictorial ad hoc scale (e.g., a picture of a bow vs. a picture of a bow and a purse). The current results would be further strengthened by replications of this work where the Picture condition is a communicative act relying on nonlinguistic symbols throughout without any linguistic reasoning (as in studies of gesturing and pointing; see Grigoroglou & Papafragou, 2017, for a review).

Limitations and future extensions

The current design has some limitations. A first limitation is the highly simplified nature of the task. Children in this study were given a forced choice among three possible referents. Referential disambiguation differs from other tasks used to test quantity implicature, and the highly contrastive nature of the task may have helped children's performance. Second, and relatedly, our study used ad hoc implicatures that have been argued to be easier to compute compared with other quantity implicatures (e.g., those that rely on *some* vs. *all;* Barner et al., 2011; Foppolo et al., 2021; Horowitz et al., 2018). Even though not all studies find such an advantage for ad hoc inferences (e.g., Papafragou et al., 2018; Papafragou & Tantalou, 2004), it is important to ensure that the current results generalize to other cases of quantity inferences. Finally, the current data raise the question of how pragmatic principles apply to other forms of nonlinguistic communication besides pictures, such as maps and three-dimensional models, and whether other Gricean principles should—as expected—apply to pictures and other nonlinguistic stimuli as well as words (see Liebal et al., 2011, on children's use of pointing gestures to derive manner implicatures; cf. Sullivan et al., 2022; Tieu et al., 2019).

Conclusions

This study provides important empirical support for Grice's (1975) proposal that the processes involved in quantity implicature derivation and other pragmatic inferences apply to both linguistic and nonlinguistic competitors. The study presents evidence that children as young as 3.5 years display early competence with pragmatic inferences derived with the participation of nonlinguistic symbols, specifically pictures. This supports accounts arguing that children become fairly competent pragmatic communicators at a young age (Kampa & Papafragou, 2020; Katsos & Bishop, 2011; Papafragou & Tantalou, 2004; Pouscoulous et al., 2007; Stiller et al., 2015) and coheres with the view that children can derive rich inferences not only from what a communicator conveys to others but also from what the communicator chooses not to convey to others.

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Appendix:. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jecp.2023.105805.

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