Children and adults use pragmatic principles to interpret non-linguistic symbols

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A R T I C L E   I N F O

Keywords:
Pragmatics
Non-linguistic communication
Drawings
Scalar implicature
Language acquisition
Informativeness

A B S T R A C T

A foundational principle of communication is that speakers should offer as much information as required during conversation. Thus, if a speaker offers a statement with limited information (e.g., “I like the candle” when asked about a gift containing a candle and a sweater), the listener often takes the speaker to imply that a more informative statement (“I like the candle and the sweater”) does not hold. Classic theories of communication have proposed that the principle of informativeness extends to purposeful exchanges beyond linguistic interactions, but relevant evidence so far is limited. In a set of studies, we adopt a simple visual-world paradigm to investigate whether 4- and 5-year-old children and adults expect drawings, like utterances, to be informative in accordance with the creator’s knowledge. We find that 5-year-olds and adults (but not 4-year-olds) apply the principle of informativeness to non-linguistic symbols; furthermore, the 5-year-olds’ success in this task depends on features of the symbols. We discuss the implications of these findings for debates over the mechanisms underlying pragmatic inference, as well as for children’s developing understanding of the symbolic function of drawings.

Introduction

Language provides a direct medium for people to interact and communicate with others, but just as often, language allows people to communicate through what is left unsaid. For example, if asked whether one likes a gift containing a horribly ugly sweater and a candle, a person can respond by saying “I like the candle.” Under classic approaches to communication (Grice, 1975, 1989), people are able to both produce and interpret such utterances because they assume that conversational partners must work together to further the goals of the conversation (the Cooperative Principle). This assumption is further guided by a set of communicative principles, called maxims; for example, the Maxim of Quantity captures the expectation that speakers in a conversation should give as much information as needed for their conversational partners (and no more). Apparent violations of this maxim lead to inferences beyond what is literally communicated by the speaker. For example, if a speaker provides a statement that appears to be less informative than expected for a cooperative communicative partner (“I like the candle”), the listener interprets this statement as excluding a stronger, more informative alternative (such that the example above is taken to imply “I like the candle but not the sweater,” or “I like only the candle”).

This pragmatic inference is known as a scalar implicature (Horn 1972, 1986; Grice, 1975, 1989), since it arises from comparisons to other options on a lexical scale that the speaker could have used but chose not to (for discussion and different perspectives, see Sperber & Wilson, 1986; Carston, 1998; Levinson, 2000; Chierchia, 2004, 2006; Sauerland, 2004, 2012; Geurts, 2010; Chierchia, Fox, & Spector, 2012; Horn, 2013; Chemla & Singh, 2014; Degen & Tanenhaus, 2015). In the example above, the alternatives are contextually determined. Other scalar implicatures depend on lexical alternatives such as quantifiers and other expressions ordered in terms of logical strength (e.g., “Some of my friends like cilantro” can be used to imply “Not all of my friends like cilantro”; Hirschberg, 1985). Regardless of the specifics, by most accounts, deriving a scalar implicature involves at least four steps (e.g., Barner et al., 2011; Bretheny et al., 2013). First, the listener computes the basic, literal, meaning of the expression. Second, they generate the set of alternative sentences that might have been uttered (by substitution of scalar alternatives), given the amount of relevant information required within the conversation. Third, they restrict these alternatives by removing those that are less informative. Finally, they arrive at a more informative interpretation of the sentence by negating the remaining alternative(s).

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https://doi.org/10.1016/j.jml.2023.104429
Received 13 May 2022; Received in revised form 28 April 2023; Accepted 5 May 2023
Available online 6 June 2023
0749-596X/© 2023 Published by Elsevier Inc.
Adults typically derive conversational inferences such as scalar implicatures when appropriate (Engelhardt, Bailey, & Ferreira, 2006; de Neys & Schaeken, 2007; Huang & Snedeker, 2009a; b; Grodner, Klein, Carberry, & Tanenhaus, 2010; Frank & Goodman, 2012; Marty et al., 2013; Degen & Tanenhaus, 2015). Four- and five-year-old children do not always compute scalar implicatures in an adult-like way (Noveck, 2001; Chierchia, Crain, Guasti, Gualmini, & Meroni, 2001; Papafragou & Musolino, 2003; Guasti et al., 2005; Huang & Snedeker, 2009b; Foppolo et al., 2012, among others). For instance, in many paradigms, children accept statements that are less than fully informative such as “Some giraffes have long necks” (Noveck, 2001), when in fact all giraffes have long necks, while adults reject these statements. However, children successfully compute pragmatic inferences in paradigms that make relevant scalar alternatives accessible (Papafragou & Tantalo, 2004; Stiller et al., 2015; Skordos & Papafragou, 2016; cf. Barner, Brooks, & Bale, 2011), allow for more nuanced response choices than binary good/bad sentence judgements (Katsos & Bishop, 2011), or otherwise reduce task demands (Pouscoulous et al., 2007; Kampa & Papafragou, 2020; Long et al., 2021).

One question in the literature that merits further exploration is whether children and adults apply pragmatic principles to forms of ostensive communication beyond language. Grice (1989) proposed that other forms of purposive exchanges involve participants working towards a common goal and outlined non-linguistic applications of the conversational maxims. To take the Maxim of Quantity, just as participants in a conversational exchange are expected to provide as much information as required by their partner, participants in non-linguistic exchanges are expected to provide a contribution that is neither too more or less than required. For example, if someone is assisting with the repair of a car and the mechanic needs four screws, they are expected to hand him a total of four screws, not two or six (Grice, 1989). Other pragmatic frameworks such as Relevance Theory (Sperber & Wilson, 1986) share the basic assumption that the principles underlying pragmatic interpretation in language can be applied to other intentional signals.

More generally, the idea that human communication is a species of human rational behavior has gained wide acceptance in the literature (see Tomasello, 2010; Frank & Goodman, 2012), and there is evidence that even infants are sensitive to properties of rational agents (Gergely, Nádasdy, Csibra, & Bíró, 1995; Meltzoff, 1995; Gergely & Csibra, 1997; Csibra & Gergely, 1998; Csibra et al., 1999; Gergely et al., 2002).

Existing literature has focused on the ability of children to interpret actions (including gestures) as intentional and communicative (Baker et al., 2009; Leekam et al., 2010; Vivanti et al., 2015), with some reference to the nature of the inferences children are making (Tomasello, Call, & Gluckman, 1997; Bohn et al., 2019). However, the implications of this perspective for how children and adults derive pragmatic inferences from non-linguistic communicative stimuli such as actions, gestures, or pictures have not yet been systematically tested. For instance, it remains unknown whether children and adults can draw pragmatic inferences from underinformative non-linguistic symbols (e.g., pictures or drawings).

The mechanisms underlying non-linguistic communication tie into broader issues on the nature of pragmatic inference. Under Gricean, Relevance-theoretic and many subsequent approaches, scalar implicatures and other pragmatic computations are presumed to be the result of an extensive, rich social reasoning process in which the addressee interprets a communicative signal in line with assumptions about the context, the addressee's knowledge state, goals, etc. (such that, e.g., the activation of scalar alternatives is modulated by the speaker's own knowledge and preferences: Grice, 1975, 1989; Horn, 1972; Sperber & Wilson, 1986; Carston, 1998; Sauerland, 2004, 2012; Geurts, 2010; for alternative proposals, see e.g., Chierchia, 2004; Chierchia, Fox, & Spector, 2009; Chierchia et al., 2012; Barner, Hochstein, Rubenson, & Bale, 2018; Hochstein et al., 2018; Geurts, Kissine, & van Tiel, 2019). Existing experimental evidence shows that both adults (Berge & Grodner, 2012; Breheny et al., 2013; cf. Fairchild & Papafragou, 2018) and 4- (Kampa & Papafragou, 2020) or 5-year-old children (Hochstein et al., 2016; Papafragou et al., 2018) compute scalar implicatures in accordance with the epistemic state of the speaker. Against this background, it is important to ask not only whether children and adults bring pragmatic principles to bear on the interpretation of non-linguistic stimuli, but also whether they do so by consulting the communicator’s epistemic state.

**Drawings as communicative symbols**

Drawings provide an excellent domain to test whether pragmatic principles such as informativeness extend to non-linguistic symbols. Adults regularly use drawings and other non-linguistic symbols and actions communicatively (Uttal, 1994; Montepare, Koff, Zaitchik, & Albert, 1999; Goldstone & Sakamoto, 2003; Rentschler, Jüttner, Osman, Müller, & Caelli, 2004; Uttal et al., 2009). Drawings differ in terms of visual detail and other types of information they contain (as anyone who has used visual instructions to assemble furniture can confirm).

Children interact with drawings and pictures from early ages and can recognize faces and objects in pictures even in infancy (Dirks & Gibson, 1977; Rose, 1977; Barrera & Maurer, 1981; DeLoache & Burns, 1994; DeLoache et al., 1979). Even if they have not been exposed to pictures previously (Hochberg & Brooks, 1962), they begin to create their own drawings and pictures shortly afterwards, and by 30 months can reliably use pictures to identify real-world referents (DeLoache, 1987, 1991). For example, in a study by DeLoache (1987), an experimenter pointed to a toy that was hidden in a picture of a room and asked children to retrieve the toy. Thirty-month-old children successfully retrieved the toy, indicating an understanding that pictures can be used communicatively, although younger (24-month-old) children failed. By age 3, children can recognize that drawings can differ in their level of informativeness and can evaluate them with respect to other individuals’ goals. For instance, 3-year-olds recognize that if someone’s goal is to identify a drawing as a house, then a more detailed drawing of a house will be more useful, and a less detailed prototypical drawing will be more useful than a more detailed non-prototypical drawing (Allen, Bloom, & Hodgson, 2010). Furthermore, children from an early age reason about drawings in terms of the intentions of their creator. In one study (Preissler & Bloom, 2008), when an adult artist drew an object, 2-year-olds later mapped a novel name for the drawing to the object that the adult had been looking at; further manipulations showed that this response was not merely because there was more attention given to that object. This sensitivity to creator’s intent extends to other artefacts (see Gelman & Bloom, 2000; Jaswal, 2006; but see Richert & Lilard, 2002).

Despite these early successes, interpreting pictorial symbols requires an understanding of dual representation, the idea that symbols are both physical entities and abstract representations of something else (Uttal, Schreiber, & DeLoache, 1995; DeLoache, 1987; DeLoache, 1995; DeLoache, 2000; DeLoache, 2002; Tomasello, Striano, & Rochat, 1999; Uttal et al., 2009), and children sometimes struggle to overcome the physical nature of a symbol to access its abstract representational role. For example, in one study by DeLoache (2000), 3-year-olds were initially able to use a 3D scale model to retrieve a hidden object in a room that was identical to the scale model. However, when the physical nature of the 3D model was emphasized by having children play with it first, 3-year-olds subsequently failed to use the model abstractly to retrieve the object. The opposite was also true: 2.5-year-olds initially failed to retrieve the object hidden in the room when presented with a 3D scale model, but when the abstract nature of the 3D model was emphasized by putting it behind a screen, they succeeded.

So far, this work has not considered the inferences children might derive from what drawings omit in addition to what they contain (i.e., scalar inferences from drawings). Given the inherently selective nature of symbols such as drawings (i.e., an artist rarely depicts everything they see), it is an open question whether children recognize that the choice to include some visual details but not others depends on one’s wish to be informative, given one’s knowledge and the goals of the exchange. This
is particularly important since – unlike language - children may lack practice in interpreting drawings this way. Furthermore, understanding drawings pragmatically involves generating (and negating) relevant, more-informative drawings – a process that may be challenging for young learners. Consistent with this possibility, in a study in which children were asked to draw a display, 7- to 10-year-olds adapted their drawings to a partner when told that their drawings would be used in a communicative game, but 4- to 6-year-olds could not readily adapt their drawings to the context (Light & Simmons, 1983). Additionally, children’s ability to produce recognizable drawings is tied to their ability to identify the distinctive features of categories, which undergoes continued development during these years (Long, Fan, Chai, & Frank, 2019).

Current study

In three experiments, we investigated whether children and adults use informativeness to derive scalar inferences from drawings. We adapted a simple paradigm from a previous study (Kampa & Papafragou, 2020) in which even young children were shown to compute scalar inferences from a speaker’s sentence in accordance with the speaker’s epistemic state. The paradigm itself was inspired by visual-world studies of referential communication that manipulate whether participants and another agent share visual access to a display to assess sensitivity to others’ knowledge (e.g., Nadjig & Sedivy, 2002).

In the present version of the paradigm, participants (4-year-olds, 5-year-olds and adults) were presented with a pair of photos, each depicting a girl (“Danielle”) facing the participant from behind a two-compartment box. The box compartments contained identical toys across the two photos. However, in one photo, both the participant and the girl had full visual access to the two compartments of the box (e.g., they could both see that the box contained a penguin and a pumpkin; full knowledge). In the other photo, the participant had full visual access to both compartments of the box, but the girl could only see one compartment because the other one was blocked from her view (e.g., Danielle could see that the box contained a penguin but could not see the pumpkin; limited knowledge). Participants were told that Danielle would look at each box, then draw what she sees in one of the boxes. Their task would be to decide which box she chose. At the end of the trial, participants saw the girl hold up a line drawing of either one object (a penguin) or two objects (a penguin and a pumpkin), and heard a female voice say: “I see this!” Next, they were asked: “Which box did she draw?”

Applying the Maxim of Quantity, we expected adults to match a more informative (two-object) drawing with a full-knowledge communicator, given that the limited-knowledge communicator could not see and communicate about both objects. Success on this type of trial required visual perspective-taking, since both boxes had identical contents from the participant’s viewpoint. On Quantity grounds, we also expected adults to match a less informative (single-object) drawing with a limited-knowledge communicator, given the pragmatic expectation that a full-knowledge communicator should not fail to present complete and relevant information (i.e., the full contents of the box). Because the object depicted in the one-object drawing was present in both boxes (e.g., both boxes contained a penguin), participants could not choose the correct box on the basis of perspective-taking alone without considering pragmatic expectations about the amount of information a communicative drawing should contain. Of interest was whether children would also succeed on both of these two trial types, or, alternatively, whether there would be developmental differences between 4- and 5-year-olds. Furthermore, since the less informative trials offered a more stringent test of sensitivity to the principle of informativeness, we were interested in comparing success with less vs. more informative drawings across age groups: lower accuracy with less informative compared to more informative drawings would point to specific difficulties with scalar implicature and not with perspective taking more generally (perhaps especially so for children). As a point of comparison, in a closely matched version of this task (Kampa & Papafragou, 2020, Exp.1) in which Danielle uttered a statement about the contents of the box (“I see a penguin” or “I see a penguin and a pumpkin”) instead of producing a drawing, both 4- and 5-year-olds could identify the box that Danielle was talking about. In fact, 5-year-olds were as good as adults regardless of trial type and even the 4-year-olds differed from older children and adults only in the less informative trials.

In Experiment 1, we use this paradigm to assess how children (and adults) interpreted the use of non-linguistic symbols such as drawings. In Experiments 2 and 3, we extended our main findings by changing properties of the drawings in connection to their symbolic function. Notice that even though Danielle’s communicative contribution contained some language (“I see this!”), the scalar alternatives being assessed throughout were pictorial (specifically, other drawings that Danielle could have produced but did not).

Experiment 1

Data availability

All data, analysis code, and research materials for the paper are available at https://osf.io/6t9a7/.

Methods

Participants

Twenty-five 4-year-olds (Mage = 4.7, range: 4.0 to 4.11, 15 female, 10 male) and twenty-five 5-year-olds (Mage = 5.5, range: 5.0–5.11, 14 female, 11 male) participated. Children were recruited from Newark (DE) preschools and the Delaware Children’s Museum in Wilmington, DE. Three additional 4-year-olds contributed data, but were excluded for failing preliminary tests (see Procedure for criteria). Twenty-five adult participants (Mage = 27.4, range: 18–35, 9 female, 16 male) were also tested. Adult participants were recruited with a HIT (Human Intelligence Task) posting on MTurk. All participants were monolingual speakers of English. Sample sizes were based on Kampa and Papafragou (2020). Informed consent was obtained for experimentation with human subjects.

Procedure

For child participants, the experiment began with a warm-up phase designed to introduce the types of photographs used in the main task. Participants were first presented with a single photo on a computer screen (Fig. 1). The photo depicted a girl sitting across from and facing out towards the participant. In front of her was a cardboard box with two vertical compartments. The compartment to the left (from the participant’s viewpoint) was see-through and empty. The compartment to the right contained an object (a teacup) but was blocked so that only the participant but not the girl could see its contents.

The children were told that the girl in the photo was the experimenter’s friend, Danielle, and that she had a special box in front of her. The children were then asked whether they themselves could look through the two parts of the box (“Can you look through this side?”), and if not, why not. (For the blocked compartment, the children typically said “no” and mentioned that it was closed or blocked.) Children were asked if they thought Danielle could look through the blocked side (“So do you think she can look through that one?” “<pointing>.”). The children were then asked whether Danielle knew about the item in the blocked compartment (“Does she know there’s a teacup there?”). The children who incorrectly replied that the girl knew the identity of the object in the blocked compartment were given corrective feedback (n = 4; “No, I don’t think she knows there’s a teacup there because she can’t look through that side; it’s blocked”).

All participants then completed two pre-test trials. In each trial, two photos were shown side by side. One photo showed Danielle and a
limited-access box similar to the warm-up phase; the other showed Danielle and a full-access box where both compartments were unobstructed. One photo appeared on screen, followed by the other one after 2s, as the experimenter explained the task (presentation order/side of the screen for the limited access box photo was counterbalanced across participants). Participants were told that they were going to play a game with the boxes. The experimenter explained that Danielle would look at each box and, pointing to each side of the boxes, reminded children whether it was open so that Danielle could look through it or closed so that she could not. Participants were told, “[Danielle] is going to draw what she sees in just one of the boxes, and you have to decide which box she chose.” After this explanation ended (and both photos had stayed up for 2s), a third photo appeared above the other photos which depicted Danielle holding up a drawing on a piece of white paper (see, for example, Fig. 1; in subsequent trials, each photo automatically appeared 2s after the previous photo); when this picture appeared, children heard a generic recorded sentence from a female speaker that said “I see this!” Participants were asked, “Which box did she draw?” Both photos remained on screen until children responded. The two boxes had different contents, so the drawing unambiguously depicted one of them. For instance, in pre-test trial 1, the full-access box had a spoon and a doll, the limited-access box had a cup and a giraffe, and the girl held up a drawing of a spoon and a doll (depicted as two separate objects on a single piece of white paper; Fig. 1). In pre-test trial 2, the full access box had two objects, but the limited-access box only had an object in the blocked compartment, and nothing in the open compartment. The drawing canvas was empty to indicate that there was nothing to see in the limited-access box. Because the trials in the critical testing condition present drawings of only one object, the pre-test trials were specifically designed to avoid presenting a drawing of one object when the contents in the boxes unambiguously differed, so as not to influence children’s performance on critical test trials. No feedback was given during pre-test trials, and all children passed at least one of the pre-test trials and continued with the study.

The drawings were created using an online photo-to-line-drawing converter. Each object from the boxes was photographed individually against a white background, then that photo was converted into a black-and-white drawing and presented as described (see Fig. 1). The drawings were slightly smaller than their corresponding objects in the photos, at a ratio of approximately 7:10. For easy correspondence to the content of the boxes, the visual orientation of the object(s) in the drawing was not entirely faithful to the visual perspective of the girl. There is no reason to believe that this in itself was an issue for participants (see especially results from Experiment 3).

Participants then completed 8 test trials. The set-up was the same as the pre-test trials; three photos appeared on the screen in succession from left to right with a 2s delay in between each photo (Fig. 2). As the third photo appeared at the top, participants heard an audio recording from a female speaker that said “I see this!” Critically, for the test trials, the contents of the boxes within a trial were identical (e.g., a spoon and a bowl) but only one of the objects in the limited-access box (here, the spoon) was visible to the experimenter’s friend. There were two within-subject conditions (More-Informative, Less-Informative) depending on whether children saw a more informative drawing depicting both objects (e.g., a drawing of a spoon and a drawing of a bowl placed on the same canvas) or a less informative drawing depicting only a single object – the one that remained visible to the speaker in the limited-access box but was present in the other box too (e.g., a spoon). Participants were again asked, “Which box did she draw?”.

For test trials 1–4, the girl in the photos was Danielle; for trials 5–8, the girl in the photos was Julia, another friend of the experimenter’s (the pre-recorded statements had a different female voice for Julia). Participants were given 4 more-informative and 4 less-informative test drawings in a mixed order, always beginning with a more-informative one (for the role of the availability of a logically stronger relevant alternative, see Skordos & Papafragou, 2016). Two presentation lists were created; assignment of statements corresponding to each condition (More-Informative, Less-Informative) to trials was counterbalanced across lists. The position of the limited access box photo across trials was also counterbalanced within each list.

To introduce Julia, and to remind children of the critical properties of the boxes, after the first 4 test trials, children were presented with a reminder trial and questions that were modeled after the warm-up phase. The trial included a photo of a new friend, Julia, and a limited-access box with only one object (a blue plastic cup in the blocked compartment). As in the warm-up phase, children were asked whether they could look through each side of the limited-access box, and whether Julia could look through the blocked side (for the importance of such reminders of the visual properties of the display, see Nadig & Sedivy, 2002). No feedback was given. We also asked whether Julia knew about the contents of the blocked compartment (“Does she know there’s a cup there?”). Children who replied “yes” to this question in both the warm-
up and this reminder phase were excluded since they did not understand the nature of the limited-access box (n = 3 4-year-olds).

To reiterate, two patterns should emerge if participants could successfully extend pragmatic principles and incorporate the perspective and knowledge of the creator of the drawings into their responses on test trials. In the More-Informative condition, they should take the more informative drawing (both objects) to describe the full access box and thus belong to the fully knowledgeable agent, because the girl could not see the bowl in the limited-access box. In the Less-Informative condition, they should take the less informative drawing (e.g., only a penguin) to describe the limited-access box (and thus belong to the limited-knowledge agent) because it would be under-informative (i.e., violate pragmatic expectations) under these circumstances for the full-knowledge agent) because it would be under-informative (i.e., violate pragmatic expectations) under these circumstances for the full-knowledge agent to only draw one object when they see two, especially when that second object is needed to disambiguate. Notice that these responses in both conditions presuppose sensitivity to agent knowledge since from the participant’s perspective both boxes have identical, visible contents. However, agent knowledge alone is not sufficient to succeed in the critical Less-Informative condition, since the object depicted in the less informative drawing is visible to the agent in both boxes (e.g., she draws a penguin, and both boxes contain a penguin); it is only through considering the amount of information that the agent chose to present (maxim of Quantity) that the participant has a basis to reject the full-access box (for which a drawing of one object would be insufficient) and select the limited-access box.

Coding

A correct response was defined as selecting the full-access box in the More-Informative condition and the limited-access box in the Less-Informative condition. Participants were given a score of 0 or 1 for each trial accordingly.

Results

We analyzed the data using multi-level logistic mixed effects modeling. All models were fit using the glmer function of the lme4 package (Bates, 2005; Bates, Maechler, & Bolker, 2011; Bates, Maechler, Bolker, & Walker, 2015; Bates & Sarkar, 2007) in the R Project for Statistical Computing (R Development Core-Team, 2012). Interactions that did not significantly improve model fit (assessed via a model comparison) were removed from the final model. Accuracy (by trial) was analyzed with a model that included Condition (More-Informative, Less-Informative) and Age (Adults, 5-year-olds, 4-year-olds) as fixed predictors. Computational issues due to the overparameterization of the random effects structure in the initial maximal model (Barr et al., 2013) were addressed through the iterative model reduction process suggested in Bates et al. (2018), whereby the correlation between random effects was dropped first and individual random effects were removed in the order of lowest variance until the model converged, in order to keep the random effects structure as informative as possible. The random slope of Condition by subject was dropped from all maximal models due to convergence failure. The final random effect structure specified intercepts by item and subject for all reported models. Fig. 3 summarizes the data.

Both fixed predictors were included in the final model: Condition (More-Informative, Less-Informative) as a first-level predictor, and Age (Adults, 5-year-olds, 4-year-olds) as a second-level predictor. The fixed effect of Condition was coded with centered contrasts (-.5, .5). The fixed effect of Age was analyzed using a Helmert coding scheme with two simple contrasts, first, comparing adults to children (c1 = -.66, .33, .33), then 5-year-olds to 4-year-olds (c2 = 0, -.5, .5). The same coding and analytic strategy was followed in all subsequent experiments. Table 1 presents the parameter estimates for the multi-level model.

The model revealed an effect of Condition: participants performed better in the More-Informative condition than the Less-Informative condition (Mmore = .78, Mless = .66; β = -.80, z = 7.18, p < .001). The model also revealed an effect of Age when adults were compared to children: unsurprisingly, adults performed better (MAdult = .83, MChild = .67; β = -1.34, z = -2.89, p = .003). There was no effect of Age when 4-year-olds and 5-year-olds were compared to each other (M4yos = .62, M5yos = .73; β = 0.67, z = 1.43, p = .15). Finally, there was no significant interaction between Condition and Age (regardless of how Age was coded).

In order to determine whether each age group’s performance in the More-Informative and Less-Informative conditions significantly differed from performance expected by chance, we conducted a one-sample t-test with a test value set at 0.5 (two referent choices) for each age group and condition. All age groups performed significantly differently from chance in the More-Informative condition (Adults: M = .86, t(24) = 6.65, p < .001; 5-year-olds: M = .80, t(24) = 6.00, p < .001; 4-year-olds: M = .69, t(24) = 2.57, p = .017), but only adults and 5-year-olds performed significantly differently from chance in the Less-Informative condition (Adults: M = .80, t(24) = 5.04, p < .001; 5-year-olds: M = .66, t(24) = 2.22, p = .036; 4-year-olds: M = .54, t(24) = .49, p = .62). Finally, an inspection of errors revealed that their number was roughly equal.
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olds performed significantly worse than adults in this task; furthermore,
knowledge, in accord with pragmatic principles. Thus, adults generated
limited knowledge and a more informative drawing to a creator with full

correctly matched both a less informative drawing to a creator with

stimuli (Kampa & Papafragou, 2020). What could be responsible for
equivalent between the first and second half of the trials for all age
groups (Adults: n = 16 vs. 18, 5-year-olds: n = 32 vs. 22, 4-year-olds: n = 38 vs. 39 respectively), hence performance did not depend on learning the logic of the task during the experiment.

Discussion

Experiment 1 found that adults applied the principle of informativeness to communicative exchanges with non-linguistic symbols: they correctly matched both a less informative drawing to a creator with limited knowledge and a more informative drawing to a creator with full knowledge, in accord with pragmatic principles. Thus, adults generated and negated relevant alternatives for non-linguistic symbols: when a creator presented a drawing (e.g., a penguin and a pumpkin), they inferred that the more informative alternative was not true. However, 4- and 5-year-olds performed significantly worse than adults in this task; furthermore, the two child groups did not differ from one another (even though in 5-year-olds, unlike 4-year-olds, performance was reliably different from chance in both conditions). Additionally, for both adults and children, the Less-Informative condition was more difficult, presumably because it introduced scalar reasoning to a task that already involved taking someone else’s visual (and epistemic) perspective.

The present findings contrast with 4- and 5-year-old’s success in a previous, otherwise identical study that used linguistic utterances as stimuli (Kampa & Papafragou, 2020). What could be responsible for children’s difficulties? One possibility stems from the fact that children sometimes struggle with the idea that symbols are both physical entities and abstract representations of something else (Uttal et al., 1995; DeLoache, 1987; DeLoache, 1995; DeLoache, 2000; DeLoache, 2002; Uttal et al., 2009). Inspired by this work, we identified an aspect of our design that could have increased the pull of the physical dimension of the drawings, thereby making it harder for children to treat them as abstract representations of the objects in the boxes, especially when these representations were meant to be intentionally selective as in the Less-Informative trials. Recall that the placement of the drawings in the Less-Informative trials was faithful to the actual display: the drawings were presented on the left side of the canvas (with blank space on the other side.) We hypothesized that disrupting the symmetry between the drawing and the display configuration in the Less-Informative condition (e.g., by placing the drawing in the middle of the canvas) might make it clearer that the image is meant as a symbol that is intentionally selective. Experiment 2 tested this possibility.

Experiment 2

Methods

Participants

Twenty-five 4-year-olds (Mage = 4;8, range: 4;2 to 4;11, 13 female, 12 male) and twenty-four 5-year-olds (Mage = 5;4, range: 5;0–5;11, 12 female, 13 male) participated. Children were recruited from Newark (DE) preschools and the Delaware Children’s Museum in Wilmington, DE. Seven additional children contributed data, but were excluded for failing preliminary tests (see Procedure for criteria). Twenty-five adults (Mage = 29.8, range: 21–35, 11 female, 14 male) also participated. Adult participants were recruited with a HIT (Human Intelligence Task) posting on MTurk. All participants were monolingual speakers of English. None of them had participated in our earlier experiment.

Procedure

Experiment 2 used the same photos, drawings, procedure, etc. as Experiment 1 but placed the drawings for the Less-Informative condition in the middle of the canvas instead of on the left side. As before, participants were excluded for failing both of the pre-test trials (n = 1 4-year-old, 1 5-year-old) or for saying “yes” when asked whether Danielle knows the identity of the object in the blocked compartment during
both warm-up and reminder trials (n = 5 4-year-olds).

Coding

Coding was identical to Experiment 1.

Results

The same data analytic strategy as Experiment 1 was used. Accuracy (by trial) was analyzed with a model that included Condition (More-Informative, Less-Informative) and Age (Adults, 5-year-olds, 4-year-olds) as fixed predictors and Subjects and Items as random intercepts (see Fig. 3 and Table 2). The model showed an effect of Condition: participants performed better in the More-Informative condition than (see Fig. 3 and Table 2). The model also revealed an effect of Age when adults were compared to children (M_{Adult} = .91, M_{Child} = .60; $\beta = .80, z = 7.18, p < .001$). There was no effect of Age when 4-year-olds were compared to 5-year-olds (M_{4yos} = .57, M_{5yos} = .64; $\beta = .38, z = 1.03, p = .30$). Finally, there was no significant interaction between Condition and Age (regardless of how Age was coded).

A series of one-sample t-tests showed that performance on More-Informative trials was different from chance (0.5) for adults and 5-year-olds, but not 4-year-olds (Adults: $M = .93, t(24) = 14.01, p < .001$; 5-year-olds: $M = .70, t(23) = 3.83, p = .001$; 4-year-olds: $M = .63, t(24) = 2.01, p = .06$). A separate series of one-sample t-tests showed that performance on Less-Informative trials was different from chance for adults but not for children in either age group (Adults: $M = .88, t(24) = 7.56, p < .001$; 5-year-olds: $M = .58, t(23) = 1.28, p = .21$; 4-year-olds: $M = .51, t(24) = .14, p = .89$).

To compare across experiments, we ran a model that included Condition (More-Informative, Less-Informative), Age (Adults, 5-year-olds, 4-year-olds), and Experiment (Experiment 1, Experiment 2) as fixed predictors, and Subjects and Items as random intercepts (Table 3). As in previous analyses for Experiments 1 and 2, the model revealed an effect of Condition ($M_{More} = .77, M_{Less} = .65; \beta = -.73, z = -4.82, p < .001$). There was also an effect of Age only when adults were compared to children ($M_{Adult} = .87, M_{Child} = .64; \beta = -1.85, z = -5.78, p < .001$) but not when 4-year-olds and 5-year-olds were compared to each other ($M_{4yos} = .59, M_{5yos} = .69; \beta = 0.53, z = 1.73, p = .08$). There was no significant effect of Experiment, and no interactions between factors were significant (regardless of how Age was coded).

Discussion

Experiment 2 showed that the spatial positioning of the drawings did not appear to be a critical component in children’s interpretation of symbols in Experiment 1: performance did not improve when the drawings were presented in the center of the canvas.

An alternative explanation for children’s persistent difficulties could be that, in both Experiment 1 and 2, the drawings were highly detailed and visually interesting. As dual representation theory suggests

<table>
<thead>
<tr>
<th>Effects</th>
<th>Estimate</th>
<th>SE</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.6133</td>
<td>0.2240</td>
<td>7.203***</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative)</td>
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<td>0.2109</td>
<td>-3.157**</td>
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<td>Age (Adults vs. children)</td>
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<td>0.4279</td>
<td>-5.403***</td>
</tr>
<tr>
<td>Age (4-year-olds vs. 5-year-olds)</td>
<td>0.3829</td>
<td>0.3726</td>
<td>1.028</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative): Age (Adults vs. children)</td>
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<td>0.5847</td>
<td>0.022</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative): Age (4-y vs. 5-year-olds)</td>
<td>-0.0618</td>
<td>0.4566</td>
<td>-0.135</td>
</tr>
</tbody>
</table>

Note. Significance levels: * p < .05, ** p < .01, *** p < .001.

Table 3 Parameter estimates for accuracy in Experiment 1–2.

Note. Significance levels: * p < .05, ** p < .01, *** p < .001.

(Deloache, 2000; Uttal et al., 2009), those features might have made it difficult for children to resist the physical dimension of the drawings. If so, reducing the level of detail in the drawings might help children overcome the limitations observed in Experiments 1 and 2 and treat drawings as abstract, often selective representations of the objects in the boxes. Experiment 3 pursued this possibility.

Experiment 3

Methods

Participants

Twenty-four 4-year-olds ($M_{age} = 4;5$, range: 4;0 to 4;10, 14 female, 10 male) and twenty-five 5-year-olds ($M_{age} = 5;7$, range: 5;0–5;10, 15 female, 10 male) contributed data. Children were recruited from Newark (DE) preschools and the Delaware Children’s Museum in Wilmington, DE. An additional three children participated, but were excluded from data analyses for failing to meet inclusionary criteria (see Procedure). Twenty-five adults ($M_{age} = 27.6$, range: 19–34, 6 female, 19 male) also participated. Adult participants were recruited with a HIT (Human Intelligence Task) posting on Mturk. All participants were monolingual speakers of English. None of them had participated in our earlier experiments.

Procedure

Experiment 3 used the same photos, procedure, etc. as Experiment 1, but the drawings were made more schematic (see example drawing in Fig. 3) by removing unnecessary lines, shading, and other details using Photoshop. As before, participants were excluded for saying “yes” when asked whether Danielle knew the identity of the object in the blocked compartment during both warm-up and reminder trials (n = 2 4-year-olds, 1 5-year-old).

Coding

Coding was identical to Experiments 1 and 2.

Results

The same data analytic strategy as Experiments 1 and 2 was used. Accuracy (by trial) was analyzed with a model that included Condition (More-Informative, Less-Informative) and Age (Adults, 5-year-olds, 4-year-olds) as fixed predictors and Subjects and Items as random intercepts (see Fig. 3 and Table 4). The model revealed an effect of
Condition: participants performed better in the More-Informative than the Less-Informative condition ($M_{More} = .85$, $M_{Less} = .74$; $\beta = -0.86$, $z = -3.55$, $p < .001$). The model also revealed an effect of Age: adults performed significantly better than children ($M_{Adult} = .88$, $M_{Child} = .75$; $\beta = -1.14$, $z = -2.38$, $p = .02$) but in addition, 5-year-olds performed significantly better than 4-year-olds ($M_{4yos} = .85$, $M_{5yos} = .66$; $\beta = -1.35$, $z = -2.70$, $p = .007$). There was no significant interaction between Age and Condition (regardless of how Age was coded in the model).

A series of one-sample t-tests showed that both adults’ and 5-year-olds’ performance was significantly different from chance (0.5) on both More-Informative and Less-Informative trials, but 4-year-olds performed differently from chance only on More-Informative trials (More-Informative - Adults: $M = .91$, $t(24) = 11.36$, $p < .001$; 5-year-olds: $M = .88$, $t(24) = 12.97$, $p < .001$; 4-year-olds: $M = .77$, $t(23) = 4.66$, $p < .001$; Less-Informative - Adults: $M = .86$, $t(24) = 7.36$, $p < .001$; 5-year-olds: $M = .81$, $t(24) = 5.80$, $p < .001$; 4-year-olds: $M = .55$, $t(23) = 50$, $p = .222$).

To compare across all experiments, we ran a model that included Condition (More-Informative, Less-Informative), Age (Adults, 5-year-olds, 4-year-olds), and Experiment (Experiment 1, 2, 3) as fixed predictors and Subjects and Items as random intercepts (Table 5). To investigate whether the features of the drawings impacted performance, the fixed effect of Experiment was analyzed with a contrast ($c_1 = -.66$, $c_2 = .33$) comparing Experiment 3 (schematic drawings) to Experiments 1 and 2 (complex drawings). As in previous analyses for Experiments 1 and 2, the model revealed an effect of Condition: participants performed significantly better in the More-Informative condition than the Less-Informative condition ($M_{More} = .80$, $M_{Less} = .69$; $\beta = -0.77$, $z = -5.72$, $p < .001$). There was also an effect of Age: across experiments, adults performed significantly better than children ($M_{Adult} = .87$, $M_{Child} = .68$; $\beta = -1.64$, $z = -6.14$, $p < .001$), and 5-year-olds performed significantly better than 4-year-olds ($M_{4yos} = .61$, $M_{5yos} = .74$; $\beta = 0.77$, $z = 2.94$, $p = .003$). Importantly, performance was significantly better in Experiment 3, which used schematic drawings, than in Experiments 1 and 2, which used abstract drawings ($M_{Exp1} = .73$, $M_{Exp2} = .79$; $\beta = -0.59$, $z = -2.37$, $p = .02$). There were no significant interactions (regardless of how Age was coded).

### Discussion

In Experiment 3, we found that decreasing the level of detail in the drawings, thereby emphasizing their abstract nature, significantly improved overall performance. Adults continued to perform better than children; furthermore, as in previous experiments, the Less-Informative condition was more challenging than the More-Informative condition for all age groups, presumably because of its added demands (scalar reasoning in addition to perspective taking).

However, 5-year-olds performed better than 4-year-olds; furthermore, comparisons to chance showed that both adults and 5-year-olds reliably followed expectations of informativeness for schematic drawings in both the More-Informative and the Less-Informative condition. Four-year-olds still struggled to apply pragmatic principles in the Less-Informative condition. This pattern of results, therefore, suggests that, at least for the older children in our sample, abstract drawings can be interpreted as symbols that are subject to pragmatic principles and can give rise to the equivalent of a scalar inference. We return to the reasons underlying these patterns in the General Discussion.

### General discussion

According to Grice (1975, 1989), communication relies on inference, which is governed by expectations about rational behavior. Under this approach, communicators are expected to be cooperative in order to further the goal of a conversation. One expectation is that communicators should provide as much information as required by their communicative partner (the maxim of Quantity). Listeners draw inferences about what a speaker intended based on these principles through a process of reasoning about the speaker and their goals and characteristics, such as their epistemic state. Grice and others (e.g., Sperber & Wilson, 1986) have proposed that the same principles underlie purposive exchanges beyond language, but relevant evidence so far has been limited. In a set of studies, we tested this proposal by asking whether children and adults use the pragmatic maxim of Quantity in non-linguistic communication. We adapted a simple visual-world paradigm that has been used recently with 4- and 5-year-old children to elicit successful Quantity (scalar) inferences from utterances in line with the speaker’s epistemic state (Kampa & Papafragou, 2020) to ask how drawings are understood as communicative symbols. Specifically, we tested whether children and adults could use the relative informational content of drawings to compute what kind of message the communicator had in mind.

Our findings show that, for adults, pragmatic principles apply beyond linguistic communication to non-linguistic symbols: throughout all our experiments, adults successfully interpreted drawings as representing objects, recognized that a creator would not produce a drawing of an object they could not see, and drew inferences from the omission of an object in a drawing about the scene (‘box’) that the creator intended to pick out. In the same series of experiments, 4- to 5-year-olds’ performance was systematically lower than that of adults. In all experiments, both adults and children performed worse when they had to reason about drawings that potentially violated the principle of informativeness and therefore involved scalar reasoning (Less-Informative condition) compared to drawings that could be interpreted simply via perspective-taking (More-Informative condition). Furthermore, both adults’ and children’s performance improved when the drawings were

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**Table 4**

Parameter estimates for accuracy in Experiment 3.

<table>
<thead>
<tr>
<th>Effects</th>
<th>Estimate</th>
<th>SE</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.4113</td>
<td>0.2936</td>
<td>8.213***</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative)</td>
<td>-0.8647</td>
<td>0.2438</td>
<td>-3.547***</td>
</tr>
<tr>
<td>Age (Adults vs. children)</td>
<td>-1.1401</td>
<td>0.4790</td>
<td>-2.380*</td>
</tr>
<tr>
<td>Age (4-year-olds vs. 5-year-olds)</td>
<td>-1.3533</td>
<td>0.5607</td>
<td>-2.703**</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative); Age (Adults vs. children)</td>
<td>-0.3166</td>
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<td>-0.554</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative); Age (4-y vs. 5-year-olds)</td>
<td>0.4990</td>
<td>0.5655</td>
<td>0.883</td>
</tr>
</tbody>
</table>

*Note. Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$.

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**Table 5**

Parameter estimates for accuracy in Experiment 1, 2, and 3.

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<tr>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>Condition (More-Informative, Less-Informative)</td>
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<td>-5.718***</td>
</tr>
<tr>
<td>Age (Adults vs. children)</td>
<td>-1.6438</td>
<td>0.2678</td>
<td>-6.137***</td>
</tr>
<tr>
<td>Age (4-year-olds vs. 5-year-olds)</td>
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<td>0.2625</td>
<td>2.938***</td>
</tr>
<tr>
<td>Experiment (Abstract vs. Complex Drawings); 3 vs. 1 &amp; 2</td>
<td>-0.5827</td>
<td>0.2456</td>
<td>-2.372*</td>
</tr>
<tr>
<td>Condition (More-Informative, Less-Informative); Age (Adults vs. children)</td>
<td>-0.1885</td>
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<td>-0.582</td>
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<td>Condition (More-Informative, Less-Informative); Age (4- vs. 5-year-olds)</td>
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<tr>
<td>Condition (More-Informative, Less-Informative); Experiment (1, 2, 3)</td>
<td>-0.0534</td>
<td>0.2990</td>
<td>0.858</td>
</tr>
<tr>
<td>Age (Adults vs. children); Experiment (1, 2, 3)</td>
<td>-0.9134</td>
<td>0.6847</td>
<td>-1.334</td>
</tr>
<tr>
<td>Age (4-year-olds vs. 5-year-olds); Experiment (1, 2, 3)</td>
<td>1.9382</td>
<td>0.7783</td>
<td>1.796</td>
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<tr>
<td>Condition (More, Less); Age (Adults vs. children); Experiment (1, 2, 3)</td>
<td>0.1920</td>
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<td>0.276</td>
</tr>
<tr>
<td>Condition (More, Less); Age (4-year-olds vs. 5-year-olds); Experiment (1, 2, 3)</td>
<td>-0.3014</td>
<td>0.7888</td>
<td>-0.382</td>
</tr>
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</table>

*Note. Significance levels: * $p < .05$, ** $p < .01$, *** $p < .001$. 
abstract (Experiment 3): under those circumstances, 5-year-olds performed better than younger children in our sample and could reliably use the degree of informativeness of a drawing to pick out a referent in a scene in accordance to the communicator’s mental state.

Our results reveal significant developmental difficulties in the pragmatic interpretation of non-linguistic symbols. At the same time, the data from adults and 5-year-olds provide one of the first pieces of evidence in support of the much cited but rarely tested claim that principles of communication such as the need to be informative underlie all forms of purposive exchanges (cf. Grice, 1975, 1989; Sperber & Wilson, 1986). We next examine these issues in detail.

Developmental limitations and pragmatic growth

A recurring finding across all three experiments was that 4-to-5-year-olds performed significantly worse than adults and, with the exception of Experiment 3, there were no differences between child groups. This finding is striking given that both 4- and 5-year-olds succeeded in a previous study involving a matched linguistic task (Kampa & Papafragou, 2020, Exp.1). Recall that, in that study, participants were told that Danielle would look at each box, then tell them what she saw in one of the boxes; their task would be to decide which box she was describing. At the end of the trial, participants heard a female voice say either “I see a penguin” or “I see a pumpkin and a penguin”, and were asked: “Which box is she talking about?” Adults and 5-year-old children performed at ceiling and even 4-year-olds successfully chose the limited knowledge box when Danielle was less informative (i.e., mentioned only one object) and the full knowledge box when Danielle was more informative (i.e., mentioned both objects). Against this background, how can the present difficulties be explained?

A prominent explanation for children’s difficulty using non-linguistic symbols abstractly is that children may be more familiar with using language as a communicative and referential medium compared to drawings. Even though children already know that drawings are referential by age 2.5 (DeLoache, 1987, 1991, 2000; Preissler & Bloom, 2008; Salsas & Vivaldi, 2016), and can rely on pictures to solve simple retrieval tasks (Uttal et al., 1995; DeLoache, 1987; DeLoache, 1995; DeLoache, 2000; Uttal et al., 2009), both children themselves and the adults in their environment convey information through language and not pictures for most day-to-day purposes. This asymmetry emerges early: language is used to refer to concrete objects from the earliest stages of development (Tomasello, 1992; Golinkoff, Mervis, & Hirsh-Pasek, 1994; Gillette, Gleitman, Gleitman, & Lederer, 1999; Waxman & Booth, 2003; Tardif et al., 2008) but children’s first drawings are typically scribbles that do not obviously refer to real-world entities (Luquet, 1927; Piaget & Inhelder, 1948; Krampe, 1991; Eng, 2013; Long et al., 2019, although see Matthews, 1984; Yamagata, 1997). And as mentioned already, dual representation continues to present challenges in later childhood and even into adulthood (Goldstone & Sakamoto, 2003; Kaminski, Sloutsky, & Heckler, 2009). In our experiments, since the detailed drawings were more visually interesting than the schematic ones, it could be that children were more focused on their physical nature as drawings rather than their abstract nature as representations of the toys in the box; concreteness has been shown to impede children’s ability to link symbols to their referent in a task that requires abstract reasoning (see discussion of similar cases in Uttal et al., 2009). A similar phenomenon is also seen in tasks such as the false photograph task (Zaitchik, 1990; cf. also Slaughter, 1998; Leslie, 2000), in which children fail to reject a photograph that differs from the current reality because they cannot overcome the “pull of the real” of the photograph. In Experiment 3, where the demands of dual representation were reduced through fairly small alterations to the drawings to decrease the pull of their physical representation, performance significantly improved.

Beyond understanding the general informational properties of drawings, two more specific pragmatic requirements on the use of drawings vs. words probably contributed to the present results. Recall that successfully applying the Maxim of Quantity to connect more informative (two-object) drawings to the right box required visual perspective-taking, since both boxes had identical contents from the participant’s viewpoint. Perspective taking is the bedrock of verbal communication (Baldwin, 1991; Nadig & Sedivy, 2002; Bahiyar & Kuntay, 2009; Tomasello, 2010; see Grigoroglou & Papafragou, 2018, 2019, for reviews), and children are used to performing mental operations to interpret utterances from someone else’s perspective. However, the same is not necessarily true of pictures. In fact, as mentioned in the Introduction, there is evidence that young children have difficulty adapting their drawings to others’ viewpoints (Light & Simmons, 1983).

Furthermore, success with less informative (one-object) drawings required a scalar implicature, in addition to perspective taking. Recall that deriving a scalar implicature involves a number of steps (Barner et al., 2011). Those include computing the basic, literal, meaning of the stimulus, generating a set of alternative stimuli that might have been produced (by substitution of scalar alternatives), given the amount of relevant information required by the conversation, and later negating the stronger alternatives to establish an informative interpretation of the stimulus (so as to arrive at the inference that the correct box contains only one and not two objects). Even though these steps are formally identical for both verbal and pictorial stimuli, there is a difference already in the second step of the above reasoning schema: the ease of accessing alternative, more informative relevant stimuli is bound to differ for words and drawings. We know that even young children interpret words in their input in ways that are highly attuned to contrast: for instance, acquiring the meaning of a new word often involves comparing the word to other words that the speaker could have produced (E. Clark, 1987; cf. Markman, 1994). But the process of generating and comparing alternative drawings that a communicator could have produced may not be as obvious: the alternatives themselves – unlike words – lack conventionality (E. Clark, 1987) and the pictorial scale needs to be flexibly set up from context alone.

Relatively, for these trials, there is a difference in cost expectations for linguistic vs. pictorial alternatives (for evidence that preschoolers can calculate an agent’s motivations given his or her costs, see Jara-Ettlinger, Gweon, Schulz, & Tenenbaum, 2016). Specifically, language and pictorial symbols differ in terms of their level of effort; it is relatively low effort to produce a few more words (e.g., “I see a penguin... and a pumpkin”), and thus reasonable to expect a speaker to be exhaustive in mentioning everything relevant that they see. However, the same is not true of pictures: it is relatively high effort to produce drawings, particularly the highly detailed drawings in Experiments 1 and 2, and there is rarely an expectation that an artist will draw everything that they see. This reasoning bears on the process of generating scalar alternatives for words vs. drawings: if it is low effort for a communicator to provide more information (e.g., a second Noun Phrase) but they chose not to, it is easier to interpret that omission as intentional. If it is high effort to provide more information (e.g., a second detailed drawing of an object), children may neglect to interpret its omission as intentional. This provides an additional or alternative explanation for why pragmatic performance improved in Experiment 3 that used abstract line drawings; because it would have been relatively low effort to produce a second drawing, its omission was more likely to be correctly interpreted as communicative. Four-year-olds’ continued failure in Experiment 3 could be due to a still-developing understanding of drawings as communicative rather than depictive tools.

According to the picture that emerges from this discussion, the fact that the same pragmatic principles such as the need to be informative underlie the use of both verbal and non-verbal stimuli (cf. Grice, 1975, 1989; Sperber & Wilson, 1986) does not guarantee uniform interpretive results across stimulus kinds. This idea is also consistent with recent evidence that, even within the class of lexical scalar expressions (e.g., some vs. all, warm vs. hot, etc.), there is diversity in terms of their potential to generate scalar implicatures (even though the reasons for this diversity are not well understood; van Tiel, van Miltenburg, Zevakhina,
& Geurts, 2016). For present purposes, it is worth noting that the difficulties in interpreting drawings pragmatically were not limited to children but were also echoed in adults’ occasional errors; furthermore, just like children, adults found less informative trials more difficult than more informative ones across experiments and improved when pictures were more schematic (Experiment 3). These subtle similarities between children and adults support an account that explains adult-child differences in terms of experience with the use of drawings to convey information (as opposed to a qualitative shift in pragmatic competence). Against this background, the fact that 5-year-olds succeed with simple drawings (Experiment 3) is significant, as we discuss next.

Children’s understanding of the pragmatics of symbols

The finding that 5-year-olds (under some circumstances) apply pragmatic principles to non-linguistic communicative stimuli has implications for the development of children’s symbol understanding. As alluded to earlier, children have shown success at interpreting pictures as abstract representations before age five in simple retrieval and referent selection tasks (DeLoache, 1987, 1991, 2000; Marzolf & DeLoache, 1994; Preissler & Bloom, 2008; see also Allen et al., 2010). However, when they have to use those abstract representations for more complex processes (e.g., to judge differences between appearance and reality; Zaichik, 1990; Thomas, Nye, & Robinson, 1994), they are less successful, and even adults face challenges with dual representation (Goldstone & Sakamoto, 2003; Kaminski et al., 2009). In our task, children had to not only understand that the drawings represented a real item in the boxes, but had to be able to use that abstract representation to reason about a person’s intentions in producing a drawing, the set of relevant alternative drawings they could have produced, and the relative informativeness of those drawings. Thus our data are a novel test of dual representation theory and suggest that 5-year-olds at least understand that drawings carry information not only by virtue of what they contain but also of what they leave out, although children’s ability to assess a drawing’s informational content may be impacted by the characteristics of the drawing. Relatedly, the present results confirm and extend reports that young children can consider a creator’s intent when interpreting drawings (Gelman & Ebeling, 1998; Gelman & Bloom, 2000; Richert & Lillard, 2002; Jaswal, 2006; Preissler & Bloom, 2008; cf. also Allen et al., 2010).

From a different perspective, our data have theoretical implications for current research on children’s computation of scalar inferences and other types of pragmatic meaning in language. Five-year-olds’ performance in Experiment 3 differs from several prior studies showing that children of this age have difficulty with pragmatic inferences, especially the computation of scalar implicatures. In many of these studies, children’s sensitivity to pragmatic inference was measured by the ability to evaluate and reject underinformative utterances offered either by the experimenter (Noveck, 2001; Guasti et al., 2005) or by a speaker known to be incompetent (e.g., a ‘silly puppet’; Papafragou & Musolino, 2003; Katsos & Bishop, 2011). Our paradigm differed from these earlier studies in two key respects. First, we did not ask children to explicitly assess the informational content of drawings but simply to match drawings to the display that a person was facing (and presumably intended to depict). Second, and most importantly, the content of the drawings was motivated by the visual perspective of the creator: when a drawing omitted an object in the display, this occurred because the creator’s perspective did not give access to that object. The success of the 5-year-olds in Experiment 3 confirms the conclusion that early sensitivity to scalar inference is context- and task-dependent (Noveck, 2001; Papafragou & Musolino, 2003; Papafragou & Tantalo, 2004; Guasti et al., 2005; Poucoulous et al., 2005; Katsos & Bishop, 2011).

Finally, as mentioned already, for 5-year-olds to succeed on this task, they had to not only derive pragmatic inferences from pictorial symbols but do so from the epistemic perspective of a communicator as opposed to their own. Thus our results add to the small but growing body of evidence in the literature showing that preschoolers are able to consult a speaker’s epistemic state when computing a scalar implicature (Kampa & Papafragou, 2020; Papafragou et al., 2018; Hochstein et al., 2016), as predicted by rich, Gricean and post-Gricean models of implicature computation (cf. Horn, 1972; Sperber & Wilson, 1986; Grice, 1989; Carston, 1998; Sauerland, 2004, 2012; Geurts, 2010, among others).

Final thoughts

Our findings reveal a combination of early successes and challenges in understanding the pragmatics of non-linguistic symbols: adults and even young children apply the pragmatic principle of informativeness to forms of communication beyond language, but the characteristics of non-linguistic symbols impact young children’s ability to draw inferences about what the symbols are meant to communicate. These data contribute to our understanding of how communicative inferences develop across different domains, and throw light on widely accepted but rarely tested assumptions from classic pragmatic theorizing. Future work needs to address whether and how these results generalize to other non-linguistic domains beyond drawings, such as communicative actions (Bass, Bonawitz, & Gweon, 2017; Gweon & Asaba, 2018), more intensively collaborative contexts (cf. Nadig & Sedivy, 2002), as well as pragmatic principles other than Quantity (Grice, 1975).

CRediT authorship contribution statement

Alyssa Kampa: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Visualization, Project administration. Anna Papafragou: Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This material is based upon work supported by the National Science Foundation (grant #1632849). We thank the members of the Language and Cognition lab for comments and especially June Choe for detailed feedback.

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