

# Children know what words other children know

Anonymous CogSci submission

## Abstract

To communicate successfully, we need to use words that our conversational partner understands. Adults maintain precise models of the words people are likely to know, using both prior experience with their conversational partner and general metalinguistic information. Do children also know what words others are likely to know? We asked children ages 4-8 ( $n = 62$ ) to predict whether a very young child would know each of 15 familiar animal words, all typically acquired within a 6-month range. With minimal information, even children as young as 4 made reliable predictions about the target child's vocabulary knowledge. Further, children's accuracies improved significantly over the course of development. Thus, even preschool age children are adept at inferring other children's vocabulary knowledge, and they could leverage this information to communicate effectively.

**Keywords:** communication, metalinguistic, knowledge reasoning, cognitive development

## Introduction

Imagine visiting the zoo with your friend and their 2-year-old. As you walk by the peacocks, you hear your friend say, "Do you see those blue birds?" Immediately, you know that your friend is talking to their child and not you. If they were talking to you, saying "peacock" would be perfectly clear; however, "blue bird" might be a better description for a child who has never seen a peacock before. Even when talking about the same object, we use different words depending on what we think our conversational partners know and don't know.

Adults track and adapt to their conversational partners' knowledge with relative ease. For example, adults reduce the information they give when re-telling a story to someone who has heard it before, but not when telling the story to a new partner (Galati & Brennan, 2010). Adults can adapt even to partners who are quite different from them, as in the case of parents and their children. Parents model the fine-grained details of their children's vocabularies and use these models in spontaneous communication (e.g., using "blue bird" to describe a peacock; Leung, Tunkel, & Yurovsky, in press). These vocabulary models are shaped by extensive individual parent-child interactions, but likely also general metalinguistic knowledge— for instance, that shorter words are typically simpler than longer words and more likely to be known.

In line with this conjecture, Kuperman, Stadthagen-Gonzalez, & Brysbaert (2012) asked people to report the age at which they understood a set of 30,000 English words. They found that adults typically overestimated the ages at which

words are learned, but were quite accurate at judging their relative order. Thus, even adults without children have access to the kind of metalinguistic information they could use to calibrate speech to children's knowledge.

Can children use this same kind of information to predict whether others will know words? Evidence suggests that reasoning about another person's specific lexical knowledge could be difficult for young children. Children show consistent errors in reasoning about others' knowledge, commonly over-attributing knowledge (e.g., Gopnik & Astington, 1988; Taylor, Esbensen, & Bennett, 1994). The bias to over-attribute knowledge is particularly pronounced for information that the child themselves knows, or is familiar with—both of which would be problems for reasoning about the knowledge of a younger child (Birch & Bloom, 2003; Ghrear, Fung, Haddock, & Birch, 2020).

However, even preschool age children are able to make non-egocentric knowledge judgments in some tasks. Asked about variety of general knowledge skills, young children attribute different levels of knowledge to infants, preschool children, and adults (Fitneva, 2010; Taylor, Cartwright, & Bowden, 1991). By at least age 6, children even judge adults as *less* likely than other children to know about some topics, such as toys or children's television (Fitneva, 2010; VanderBorght & Jaswal, 2009). While these studies sometimes include vocabulary items among other kinds of knowledge items (e.g., Taylor et al., 1991), they rely on large scale distinctions, such as an infant not knowing any words, a child knowing simple words (e.g., *happy*), and an adult knowing complex words (e.g., *hypochondriac*). One study suggests that children as young as 5 can make metalinguistic judgments about their *own* vocabularies, but it is unclear whether they should be able to accurately judge the lexical knowledge of others (Walley & Metsala, 1992).

We ask how children infer another child's specific vocabulary knowledge, accurately predicting the words that a younger child will know based on words' normative age of acquisition. We introduced 4- to 8-year-old children to a younger fictional child, and asked them to make judgments about the target child's knowledge of various familiar words. The accuracy of children's judgments improved reliably from 4- to 8-years of age, but even 4-year-old children showed knowledge about the words that the target child was likely to know. Further, 7- and 8-year-old children were more sen-

sitive to the difficulty of learning words than a comparison group of adults. We end by discussing children’s own explanations for why the target child would know (or not know) particular words.

## Method

### Stimuli

Our stimuli consisted of 15 words drawn from a single domain (animal words), along with corresponding images of each animal. We pulled all animal images ( $n = 45$ ) from a normed image set (Rossion & Pourtois, 2004; recoloring of Snodgrass & Vanderwart, 1980). To ensure our stimuli spanned a range of ages of acquisition (AoAs), we ranked the animal words from earliest to latest AoA, using adult estimates from Kuperman et al. (2012), and split the words into five bins. In order to select animal images that are recognizable and typically identified by a single name, we chose the three animals from each AoA bin with the highest naming agreement according to a naming task with children (Cycowicz, Friedman, Rothstein, & Snodgrass, 1997).

The resulting animal words, ordered by estimated AoA, were *dog, duck, cat, pig, fish, turtle, zebra, elephant, snake, penguin, gorilla, owl, raccoon, leopard, and lobster*. Although adult AoA estimates for these words range from 2.5 to 7.5 years old (Kuperman et al., 2012), all of these animal words are generally acquired by age 3 according to parent-report estimates of children’s vocabulary knowledge (Frank, Braginsky, Yurovsky, & Marchman, 2017). Because the youngest children in our study were 4 years old, we expected all participants to know these animal words.

### Participants

We pre-registered a planned sample of 60 children ages 4–8, with 12 children recruited for each year-wise age group. Due to overrecruitment, our final sample included 62 children (12 4-year-olds, 13 5-year-olds, 13 6-year-olds, 12 7-year-olds, 12 8-year-olds). All analyses hold when looking only at the 60 children run first chronologically. Based on a pre-registered exclusion criterion, children who failed to answer all of the questions were excluded and replaced (an additional 6 children). Families were recruited online, primarily through a US University database of families who have expressed interest in doing research or previously participated. Children completed this study over Zoom, interacting with a live experimenter who navigated a slide-style, animated Qualtrics survey.

A separate sample of 30 adults were recruited via Amazon Mechanical Turk. The adult sample provides a simple test that our task elicits robust inferences about the target child’s lexical knowledge, and that these inferences correspond to extant AoA data. Adult participants completed the same task using Qualtrics, with minor modifications as described below.

### Procedure

**Introduction.** Children were shown a picture of a child named “Sam” (seen in Figure 1). Children were anchored to Sam’s

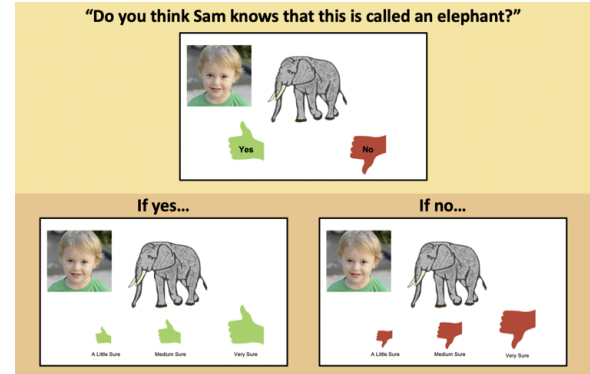


Figure 1: The structure of an example trial. The experimenter labeled the animal, then asks the child “Do you think Sam knows that this is called an elephant?” Based on their response, children were then asked to provide a confidence judgment on a 3-point scale (a little sure, medium sure, very sure).

knowledge of various familiar skills, specifically some skills that Sam has acquired (e.g., coloring), and some that Sam has not yet acquired (e.g., reading). Children were then specifically anchored to Sam’s possible word knowledge in an unrelated domain. They were given an example of one word Sam knows (*car*), and one word that Sam does not know (*piano*). This introduction was intended to familiarize the children with Sam, roughly anchor them to Sam’s knowledge and age, and to ensure that children understand there are things Sam does *not* know yet (even things children themselves likely know, such as how to read).

**Trial structure.** On each trial, children were shown a drawing of a familiar object or animal (Rossion & Pourtois, 2004). The experimenter first labeled the object (e.g., “Look, it’s [an elephant]!”), and then asked about the target child’s knowledge (e.g., “Do you think Sam knows that this is called [an elephant]? Yes or no?”). Based on their response, children were then asked a follow-up question: “How sure are you that Sam [knows/doesn’t know] that this is called [an elephant]—a little sure, medium sure, or very sure?” All questions were presented with accompanying pictures of thumbs [up/down] of varying size (see Figure 1). Children as young as 3 are able to engage in uncertainty monitoring and report their confidence, although these skills do develop in the preschool years (Lyons & Ghetti, 2011). Children’s responses to these two items were recoded onto a 1–6 scale from 1–*very sure Sam doesn’t know* to 6–*very sure Sam knows*.

The experimenter provided no evaluative feedback on any trials, but did offer consistent neutral feedback (e.g., repeating the child’s answer or saying “Okay!”). When a child failed to respond within about 5 seconds or offered a non-canonical response (e.g., saying “Maybe”), the experimenter acknowledged the child’s answer and then repeated the question with the possible responses. If a child did not answer after the question was repeated, the experimenter moved on and

marked the trial as no response. These were considered “incomplete” sessions and these participants were not included in the final sample.

**Familiarization trials.** Children first completed two non-animal familiarization trials, one for an early-acquired word (*ball*) and one for a late-acquired word (*artichoke*). These trials followed the trial structure described above and were intended to help familiarize children with the structure of the questions and scales. These trials were always asked first and in a fixed order.

**Animal trials.** Children were then shown 15 trials of the same form (see example trial in Figure 1). For the 15 animal trials, trial order was randomized across participants to control for any potential order effects in children’s responses.

**Explanation.** After completing the final animal trial, children were asked an open-ended explanation question about their final judgment (e.g., “Why do you think Sam [knows/doesn’t know] that this is called [an elephant]?”). Because the trial order was randomized, the explanations concerned different animal words across participants.

**Final check questions.** Children were asked two questions about Sam’s skill knowledge, one early-acquired skill (*going up and down stairs*) and one very late-acquired skill (*driving a car*). These questions again followed the general trial structure described above. The skill knowledge items were included as an additional check that children at all ages were able to use the scale appropriately, in case young children failed to differentiate animal words based on AoA. Lastly, children were asked to report how old they thought Sam was. This question was intended to assess another aspect of children’s belief about Sam. Sam’s photo and skill knowledge were intended to indicate toddlerhood.

**Adult procedure.** Adult participants completed a minimally adapted version of the same task online via Qualtrics. Unlike children, adults were simply presented with the full 6-point scale (1–*very sure Sam doesn’t know* to 6–*very sure Sam does know*). Additionally, the task was administered asynchronously, so adult participants did not interact with an experimenter or receive any feedback during the task. Otherwise, the adult task was identical to the child task described above.

## Results

### Familiarization trials

Children completed two familiarization trials asking about the target child’s knowledge of two non-animal words (*ball* and *artichoke*). These questions were primarily included to help children get accustomed to the general trial structure. To analyze children’s responses on these familiarization items, we used a mixed effects model using the `lme4` package in R (Bates, Mächler, Bolker, & Walker, 2015), predicting children’s knowledge judgments from the item with a random effect of participant.

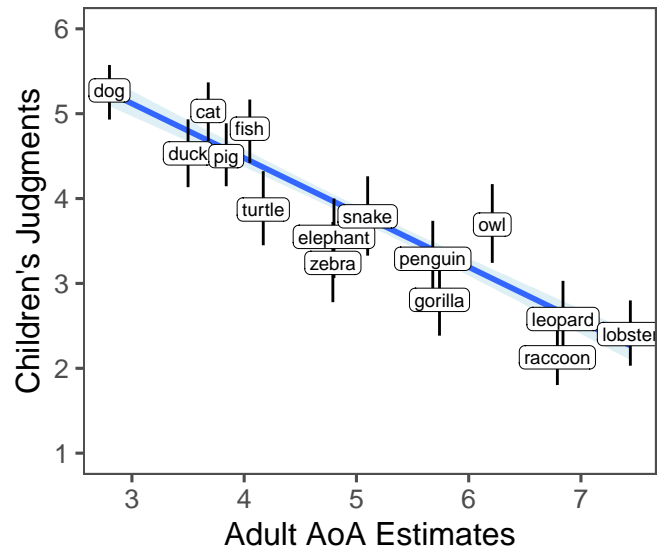


Figure 2: Comparing adult AoA estimates (in years, taken from Kuperman et al., 2012) and children’s judgments on our 6-point scale (1 = very sure Sam doesn’t know; 6 = very sure Sam knows). The black lines show 95% confidence intervals for each item. The shaded region shows the confidence interval based on a linear regression estimated from the raw data.

Overall, children were significantly more likely to report that Sam knows the word *ball* ( $mean = 4.65$ ) than that Sam knows the word *artichoke* ( $mean = 1.87$ ,  $\beta = 2.77$ ,  $t = 10.6$ ,  $p < .01$ ). Analyzing judgments separately for each age group, 4-year-olds did not significantly differentiate the two familiarization items ( $\beta = 0.17$ ,  $t = 0.21$ ,  $p = .83$ ). All other age groups significantly differentiated the two familiarization items ( $ps < 0.05$ ).

### Skill knowledge

We also included two questions about the target child’s skill knowledge. These questions were intended primarily as a check that children at all ages were able to use the scale appropriately and able to infer knowledge in an easier case. Note that the two skill items (*going up and down stairs* and *driving a car*) are in line with children’s own knowledge, unlike the animal word items. That is, child participants should be able to answer these questions appropriately even if they are reasoning egocentrically about their own knowledge.

Overall, children differentiated the target child’s skill knowledge on these two items. We used a similar mixed effects structure predicting children’s knowledge judgments from the item and a random effect of participant. Children were significantly more likely to report that the target child knows how to go up and down stairs ( $mean = 4.1$ ) than that the child knows how to drive a car ( $mean = 1.4$ ,  $\beta = 2.69$ ,  $t = 10.29$ ,  $p < .01$ ). Analyzing judgments separately for each age group, even 4-year-olds significantly differentiated the two skill items ( $\beta = 2.33$ ,  $t = 4.31$ ,  $p < .01$ ).

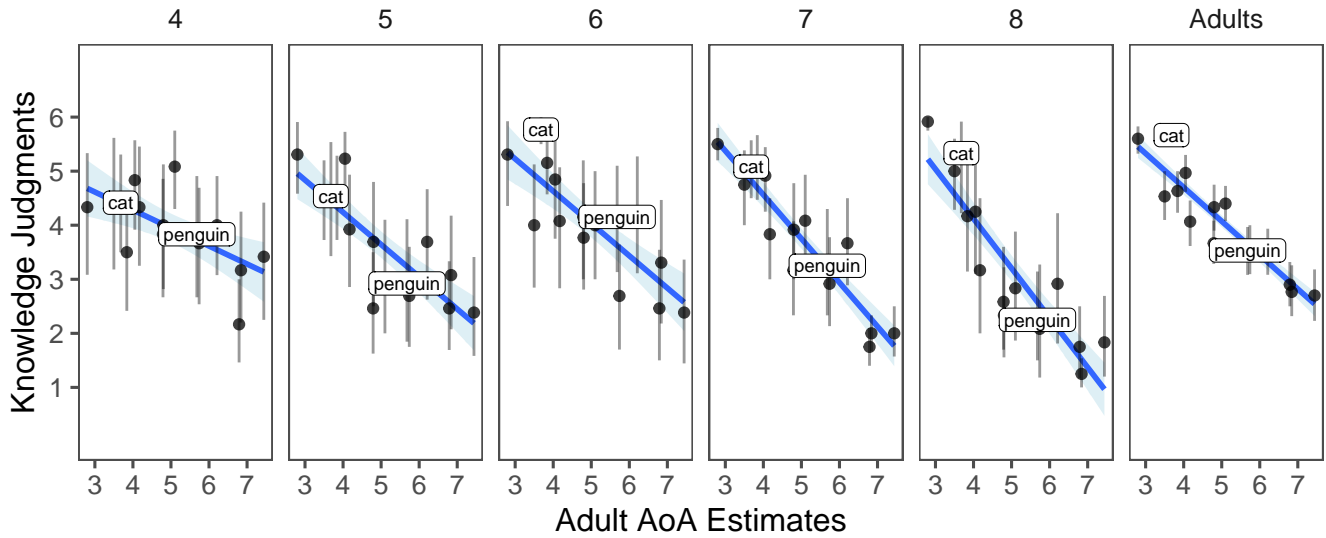


Figure 3: Children's and adults' judgements about the target child's word knowledge across development, compared with adult AoA estimates (in years, taken from Kuperman et al., 2012). Each point represents 1 of the 15 word items, with black lines showing 95% percent confidence intervals for each item. The shaded region shows the confidence interval based on a linear regression estimated from the raw data.

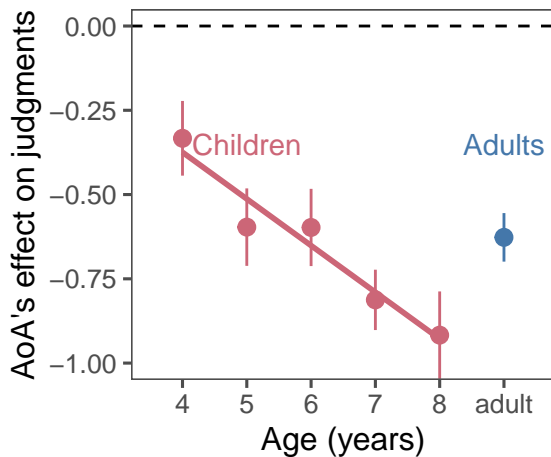


Figure 4: Coefficient estimates of the effect of age acquisition on children's and adults' knowledge judgments. Points indicate means, error bars indicate 1 SD.

### Judgments of vocabulary knowledge

Our primary analyses compare knowledge judgments on our 6-point scale to AoA judgments from adults (taken from Kuperman et al., 2012). Data were analyzed using a pre-registered mixed effects model. We predicted children's judgments from adult AoA estimates, including random effects for participant and word.

We expected that overall, children's judgments would recover the ordinal shape of age of acquisition data for these items. That is, children would infer that the target child is most likely to know early-acquired words, and least likely to know late-acquired words. As a result, we expected a nega-

tive relationship between judgments of the target child's lexical knowledge and adult AoA estimates.

First, analyzing adults responses on our task, we saw the predicted negative correlation between AoA and adults' judgments of the target child's knowledge (Figure 3,  $\beta = -0.63$ ,  $t = -8.71$ ,  $p < .01$ ). This confirmed that our task elicited reliable predictions from adults, and that adults' inferences about the target child's knowledge match predictions from AoA estimation tasks (Kuperman et al., 2012).

Do children's judgments about another child's vocabulary knowledge also reflect a sensitivity to which words are learned earlier or later? Overall, we found a significant negative effect of AoA on children's judgments ( $\beta = -0.65$ ,  $t = -8.29$ ,  $p < .001$ ). As a group, children judged that the target child would be most likely to know an early-acquired word (e.g., dog) and least likely to know a late-acquired word (e.g., lobster, see Figure 2).

We then asked whether children develop sensitivity to Sam's vocabulary knowledge, with older children's judgments recovering word-level AoA data more closely. We used the same mixed effects model but included an effect of age and an interaction between AoA and age. We again found a reliable main effect of AoA ( $\beta = -0.65$ ,  $t = -8.29$ ,  $p < .001$ ), a main effect of age ( $\beta = 0.55$ ,  $t = 3.68$ ,  $p < .001$ ) and a significant interaction between the two ( $\beta = -0.14$ ,  $t = -5.1$ ,  $p < .001$ ). As predicted, we observed that older children judged whether Sam would know each animal in a more adult-like, and more accurate, way (Figure 3).

To test the robustness of children's intuition at each age, we ran the model separately for each pre-determined year-wise age group (Figure 4). We found a significant negative correlation between AoA and children's judgments at all age

groups (with the smallest effect in 4-year-olds:  $\beta = -0.33$ ,  $t = -3.01$ ,  $p = .01$ ). That is, even 4-year-old children judged that late-acquired animal words were less likely to be known by the target child. Interestingly, the older two age-groups of children were more accurate than adults in judging Sam's knowledge (Figure 4). This appeared to be primarily driven by a greater willingness to judge Sam as moderately or very unlikely to know late-learned animal words, whereas adults were less sure about these same judgments (Figure 3). We return to this finding in the Discussion.

### How old is the target child?

At the end of the study, participants were asked to guess the target child's age. While the familiarization phase included information about the child's language and skill knowledge, no age was explicitly given. Looking at children's responses, the median response was that the target child was 3-years-old. Looking at adult's responses, the median response was that the target child was 4-years-old.

### Explanations

As an exploratory analysis, we examined the reasons young children gave for why the target child would or would not know a given word. While children sometimes offered spontaneous explanations throughout the study, this analysis focuses on the explanation elicited after the final animal trial. The explanations were divided into 6 non-mutually-exclusive categories: *Language*, *Experience*, *Location*, *Age*, *Unsure*, and *Other*.

*Language* includes explanations that explicitly appealed to language properties. *Experience* includes explanations that appeal to the child's real-world experience with the referent. *Location* includes explanations that specifically reference a particular place the animal is associated with. *Age* includes explanations that reference a particular age or general age-group. Any child that failed to answer the explanation question or expressed ignorance was coded as giving an explanation of *Unsure*. An explanation that didn't fall into any of the above categories was coded as *Other*. Note that coding was not mutually-exclusive, so explanations could be coded as including multiple categories. See Table 1 for examples of each category. Figure 5 shows the proportion of children who gave each type of explanation.

To understand how children's explanations may change over development, we divided participants into older (6-8 years old) and younger children (4-5 years old). Unsurprisingly, *Unsure* explanations were much more common in younger children (44%) when compared to older children (8.33%). *Language* explanations were used by the highest proportion of children overall (27.27%). Do older children account for all of those explanations? Although more of the older children appealed to *Language* explanations (30.56%), these explanations were also common in younger children (24%). Thus, while young children were more likely to offer no explanation, the explanations they did offer seemed to rely on factors similar to older children's explanations.

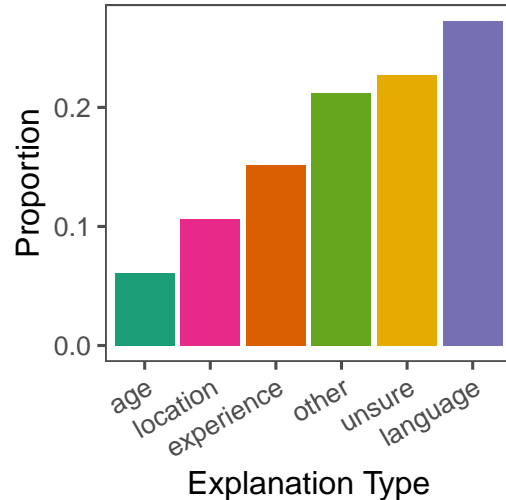


Figure 5: Children's explanations for why they think the target child knew or didn't know an animal. Categories are not mutually exclusive.

### Discussion

Our ability to infer other people's knowledge is crucial for successful communication. Young children are capable of inferring others' general knowledge states, but do they make accurate judgments about another person's specific knowledge? We asked 4- to 8-year-old children to estimate another child's knowledge of animal words, and found that children as young as 4 are sensitive to a younger child's vocabulary knowledge.

Our findings highlight that young children have robust metalinguistic knowledge (Walley & Metsala, 1992), and can use that knowledge to make highly specific inferences about other people's knowledge. The animal words used in our study are generally learned within a 6-month period, yet young children still distinguished earlier-acquired words from later-acquired words in this set. Prior studies have demonstrated that children distinguish the general knowledge of infants, young children, and adults—including some vocabulary knowledge items (Fitneva, 2010; Taylor et al., 1991). Our study further demonstrates that children readily make specific, word-level predictions about the language knowledge of another child.

Surprisingly, responses from the oldest children in our sample more closely correlated with adult judgments of AoA (Kuperman et al., 2012) than did the judgments of adult participants in this study. This difference appears to be driven by older children being more likely to judge that a young child would *not* know later-acquired words. It is possible that children may be more accurate at estimating other children's lexical knowledge because of their proximity to the age that they learned a word (see also Walley & Metsala, 1992). However, such an account should also predict that younger children would perform better than older children when making these inferences, which is counter to our developmental findings. Additionally, children and adults' estimates for the target child's age may be an important factor. In our sample,



Category	Example Utterance
Language	Because it was a very long word. Because it only has 3 letters.
Experience	Because maybe he has a dog. Because gorillas are really rare animals
Location	Because penguins live in the arctic and it's too cold for little kids... Because fish swim under the ocean.
Age	Because I think I knew that when I was around 3... Because if he went to preschool then he probably knew it...
Unsure	I don't know. I'm not sure.
Other	Because it had a longer beak than a bird. Because it's small.

Table 1: Example explanations from child participants for each of the five categories used for coding.

adults gave higher estimates for the target child's age than children did, and may have attributed more knowledge to the child more as a result.

How are children in our study making estimates about other people's knowledge? Children's own explanations suggest that they use various cues to make their estimates. Overall, language-related explanations were most common, and even preschool age children appealed to this explanation. However, such explanations are difficult to interpret, and the mechanisms underlying children's knowledge estimates are outside the scope of the current study. Future work should more directly probe the features underlying this inference—to see if children are relying on their own uncertainty, word length (and other linguistic cues), features of the referent itself, or other features.

The current work lays the foundation for future research on how children leverage their knowledge of other people to communicate successfully. While some studies have found that young children struggle in a variety of communicative tasks (e.g. Krauss & Glucksberg, 1977), other work has shown that by age 5, children selectively talk about general or specific characteristics of an object based on their partner's knowledge state (Baer & Friedman, 2018). Why might children struggle in some situations and not others? Our work can begin to address this question by mapping out whether communicative difficulties stem from tracking an interlocutor's knowledge, or problems using that information in language production. Young children eventually become effective communicators, and our work demonstrates that by age 4 children may have one key ability in place: inferring others' specific vocabulary knowledge.

Stimuli, data, and analysis code available after deanonymization.

## References

- Baer, C., & Friedman, O. (2018). Fitting the message to the listener: Children selectively mention general and specific facts. *Child Development*, 89(2), 461–475.
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, 67(1), 1–48.
- Birch, S. A., & Bloom, P. (2003). Children are cursed: An asymmetric bias in mental-state attribution. *Psychological Science*, 14(3), 283–286.
- Cycowicz, Y. M., Friedman, D., Rothstein, M., & Snodgrass, J. G. (1997). Picture naming by young children: Norms for name agreement, familiarity, and visual complexity. *Journal of Experimental Child Psychology*, 65(2), 171–237.
- Fitneva, S. A. (2010). Children's representation of child and adult knowledge. *Journal of Cognition and Development*, 11(4), 458–484.
- Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2017). Wordbank: An open repository for developmental vocabulary data. *Journal of Child Language*, 44(3), 677–694.
- Galati, A., & Brennan, S. E. (2010). Attenuating information in spoken communication: For the speaker, or for the addressee? *Journal of Memory and Language*, 62(1), 35–51.
- Ghrear, S., Fung, K., Haddock, T., & Birch, S. A. (2020). Only familiar information is a “curse”: Children's ability to predict what their peers know. *Child Development*.
- Gopnik, A., & Astington, J. W. (1988). Children's understanding of representational change and its relation to the understanding of false belief and the appearance-reality distinction. *Child Development*, 26–37.
- Krauss, R. M., & Glucksberg, S. (1977). Social and nonsocial speech. *Scientific American*, 236(2), 100–105.
- Kuperman, V., Stadthagen-Gonzalez, H., & Brysbaert, M. (2012). Age-of-acquisition ratings for 30,000 english words. *Behavior Research Methods*, 44(4), 978–990.
- Leung, A., Tunkel, A., & Yurovsky, D. (in press). Parents fine-tune their speech to children's vocabulary knowledge. *Psychological Science*.
- Rossion, B., & Pourtois, G. (2004). Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition. *Perception*, 33, 217–236.
- Snodgrass, J. G., & Vanderwart, M. (1980). A standardized

- set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6(2), 174.
- Taylor, M., Cartwright, B. S., & Bowden, T. (1991). Perspective taking and theory of mind: Do children predict interpretive diversity as a function of differences in observers' knowledge? *Child Development*, 62(6), 1334–1351.
- Taylor, M., Esbensen, B. M., & Bennett, R. T. (1994). Children's understanding of knowledge acquisition: The tendency for children to report that they have always known what they have just learned. *Child Development*, 65(6), 1581–1604.
- VanderBorgh, M., & Jaswal, V. K. (2009). Who knows best? Preschoolers sometimes prefer child informants over adult informants. *Infant and Child Development: An International Journal of Research and Practice*, 18(1), 61–71.
- Walley, A. C., & Metsala, J. L. (1992). Young children's age-of-acquisition estimates for spoken words. *Memory & Cognition*, 20(2), 171–182.