Parents Calibrate Speech to Their Children's Vocabulary Knowledge

Ashley Leung[1], Alexandra Tunkel[1], & Daniel Yurovsky[1,2]

[1] The University of Chicago

[2] Carnegie Mellon University

Author Note

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Correspondence concerning this article should be addressed to Ashley Leung, 5848 S University Ave, Chicago IL, 60642. E-mail: ashleyleung@uchicago.edu

Abstract

Young children learn language at an incredible rate. While children come prepared with powerful statistical learning mechanisms, the statistics they encounter are also prepared for them: Children learn from caregivers motivated to communicate with them. Do caregivers modify their speech in order to support children's comprehension? We asked children and their parents to play a simple reference game in which the parent's goal was to guide their child to select a target animal from a set of three. We show that parents calibrate their referring expressions to their children's language knowledge, producing more informative references for animals that they thought their children did not know. Further, parents learn about their children's knowledge over the course of the game, and calibrate their referring expressions accordingly. These results underscore the importance of understanding the communicative context in which language learning happens.

Keywords: parent-child interaction; language development; communication

Word count: X

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Variability in input related to variability in output (weisleder, hoff, fernald, hart & risely, etc). Further, not just quanitity but quality (rowe, hoff, etc.)

Where does this variability come from? One possibility is about fit–is the input at the right level of developmentally-appropriate complexity. Some evidence for developmental tuning.

Important distinction: Coarse tuning (e.g. more words to older kids) vs. fine tuning (e.g. more words specifically about what you don't know). Some indirect tests of that hypothesis with corpus data. Closest thing to a direct test is Masur's work, but even then not quite an experiment.

We seek to directly test the fine tuning hypothesis in a referential communication game.

The way we speak to children often differs from the way we speak to adults. Child-directed speech (CDS) exists across cultures, and is characterized by higher pitches and more exaggerated enunciations when compared to adult-directed speech (ADS) (Cooper & Aslin, 1990; Grieser & Kuhl, 1988). Not only do children prefer CDS over ADS, CDS is also a better predictor for language learning than overheard ADS (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013). CDS does not only differ from ADS in prosodic features- the structural qualities of CDS make speech segmentation and word learning easier (Thiessen, Hill, & Saffran, 2005; Yurovsky, Yu, & Smith, 2012). While children live in the same physical environments as adults, their *language environments* contain specific types of input that facilitate early language learning.

Children's language environments are not only suited for their abilities; they also change across development. Parents play a role in changing their children's language environment, and there is evidence suggesting that these changes aid language development.

Parents use simpler, more redundant language when talking to toddlers, and more complex syntactic structures when speaking with school-aged children (Snow, 1972). Importantly, sensitive modification of parent response shapes language learning in children (Hoff-Ginsberg & Shatz, 1982; Tamis-LeMonda, Kuchirko, & Song, 2014).

Why do parents modify the way they speak according to their children? One possible explanation is that parents are actively teaching their children. Indeed, some have posited that CDS is an ostensive cue for social learning, and that infants are born prepared to attend to these cues (Csibra & Gergely, 2009). While it may be true that parents hope to impart knowledge to their children, we argue that effective communication is the proximal goal. The field of linguistics has long established that adults communicate in ways that are efficient. Grice's (1975) maxim of quantity states that speech should be as informative as necessary, and no more. Adults are able to adhere to these maxims, adapting speech according to conversational partners' knowledge as needed for successful communication (Clark & Wilkes-Gibbs, 1986). We argue that the parent's goal to communicate with their child drives the change in language use. Specifically, parents adapt their speech according to their children's language abilities.

Parents modify their language as a *means* to achieve successful communication. Research show that parents use simpler language and are more linguistically aligned with their younger children, and these patterns of speech change as their children develop (Snow, 1972; Yurovsky, Doyle, & Frank, 2016). Parents are also sensitive to children's vocabulary knowledge, and the way they refer to objects change markedly depending on whether they are novel, comprehended, or familiar to their children (Masur, 1997). These changes in parent speech may indicate adaptations that are aimed at fulfilling the goal of effective communication, and that the language necessary to fulfill that goal changes as children develop.

Based on work by Masur (1997), we developed a study to investigate how parents adapt their speech according to their children's vocabulary knowledge. Masur's study involved parents and children engaging in unstructured free play, and parents reported their children's vocabulary knowledge after the session. Our study uses a structured interactive game that allows us to control for the amount and type of stimuli presented to the parent-child dyads, and parent-reported vocabulary measures are collected before the study. Our paradigm also introduces a communicative goal within a structured game, which also allows parent utterances to be more comparable across dyads.

We designed an interactive iPad game in which parents verbally guide their children to select animals on an iPad. Each animal in the game appeared as a target twice. We predicted that parents would modify their speech based on their beliefs about their children's vocabulary knowledge. Specifically, we predicted: (1) Parents should use shorter referring expressions when describing animals that they believe their children know, and (2) Upon the second appearance of an animal, parents would adapt the length of their referring expression according to whether the child responded accurately on the first appearance of the animal.

Method

Participants

Toddlers (aged 2.0 to 2.5 years) and their parents were recruited from a database of families in the local community or approached on the floor of a local science museum in order to achieve a planned sample of 40 parent-child dyads. A total of 46 parent-child pairs were recruited, but data from six pairs were dropped from analysis due to experimental error or failure to complete the study. The final sample consisted of 41 children aged 24 mo.; 5 days to 29 mo.; 20 days (M = 26 mo.; 5 days), twenty one of whom were girls.

In our recruitment, we made an effort to sample children from a variety of racial and socio-economic groups. Our final sample was broadly representative of the racial composition of the Chicago Area and the US more broadly (56.1% White). However, our sample was significantly more educated than the broader community (85.4% of mothers had a College or Graduate Degree).

Stimuli

Eighteen animal images were selected from the Rossion and Pourtois (2004) image set, a colorized version of the Snodgrass and Vanderwart (1980) object set. Animals were selected based on estimates of their age of acquisition (AoA) for American English learning. To obtain these estimates, we used two sources of information: Parent-report estimates of children's age of acqusition from Wordbank (Frank, Braginsky, Yurovsky, & Marchman, 2017), and retrospective self-report estimates of age of acquisition from adults (Kuperman, Stadthagen-Gonzalez, & Brysbaert, 2012, see Supporting Information for details). The age of aquisition of the selected animals ranged from 15 to 32 months. Half of the animals were chosen to have an Early age of acquisition (23-23 months), and the other half were chosen to have a Late age of acquisition (25-32 months). Each trial featured three animals, all from either the low AoA or high AoA category.

A modified version of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2007), a parent-reported measure of children's vocabulary, was administered before the testing session via an online survey. The selected animal words were embedded among the 85 in the survey. Two of the animal words–one in the early AOA (pig) and one in the late AOA category (rooster)–were accidentally omitted, so trials for those words were not included in analysis as we could not obtain individual-level estimates of children's knowledge.

Each parent-child pair played an interactive game using two iPads. Children were given two warm-up trials to get used to the iPads. The practice and experimental trials began after the warm-up. On each trial, three images of animals were displayed side by side on the child's screen, and a single word appeared on the parent's screen (Figure 1). Parents

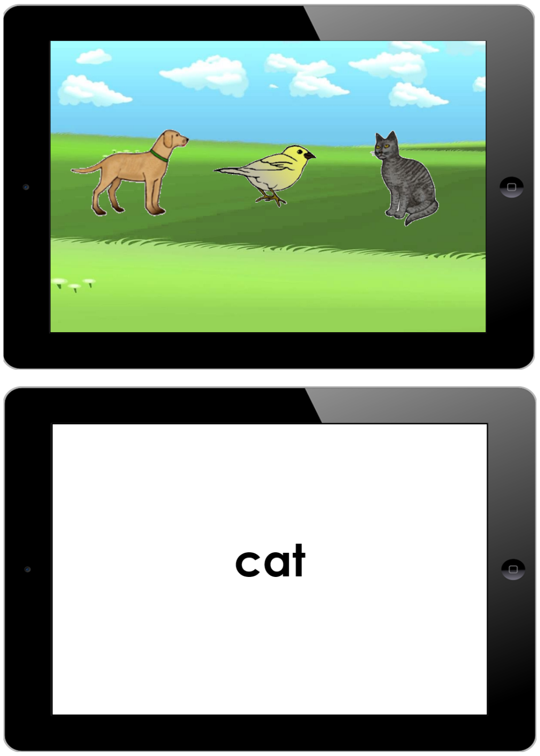

Figure 1. Example iPad screens for the child (top) and parent (bottom) during the experiment.

were instructed to communicate as they normally would with their child, and encourage them to choose the object corresponding to the word on their screen. The child was instructed to listen to their parent for cues. Once an animal was tapped, the trial ended, and a new trial began. There were a total of 36 experimental trials, such that each animal appeared as the target twice. Trials were randomized for each participant, with the constraint that the same animal could not be the target twice in a row. Practice trials followed the same format as experimental trials, with the exception that images of fruit and vegetables were shown. All sessions were videotaped for transcription and coding.

Design and Procedure

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Data analysis

The data of interest in this study were parent utterances used during the interactive game and parents' responses on the adapted CDI. Transcripts of the videos were analyzed for length of referring expressions. We measured the length of parents' referring utterances as a proxy for amount of information given in each utterance. Furthermore, utterances were manually coded for the following: use of canonical labels, basic category labels, subordinate category labels, descriptors, and comparison to other animals. Parent utterances irrelevant to the iPad game (e.g. asking the child to sit down) were not analyzed. Children's utterances were coded when audible, but were not analyzed.

Results

Word difficulty. We first confirm that the animals predicted be later learned were less likely to be marked known by the parents of children in our studies. As predicted, animals in the Early AoA category were judged to be understood by 93% of parents, and items in the Late AoA category were judged understood by 35%.

The difference between these groups was confirmed statistically with a logistic mixed effects regression (`correct ~ type + (type | subject) + (1 | word)`). The Late AoA

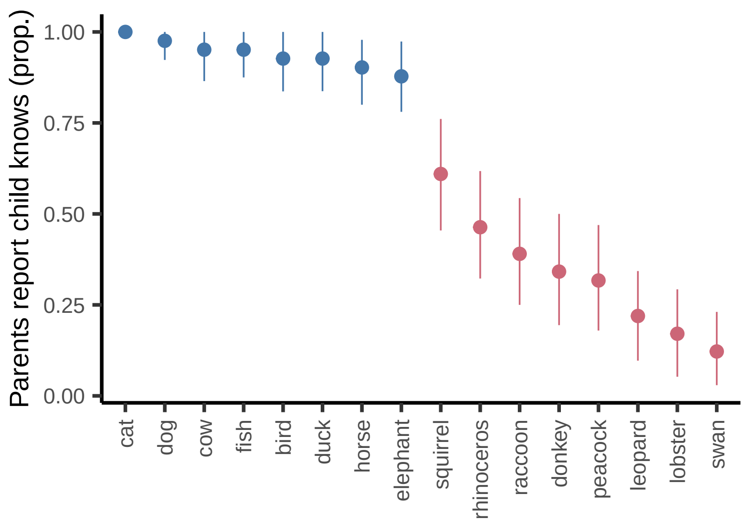


Figure 2. Proportion of parents who reported that their child understood the word for each of our target animals. Error bars indicate 95% confidence intervals computed by non-parametric bootstrap. Colors indicate apriori categorization of words into Early (blue) and Late (red) age of acquisition

items were judged known by a significantly smaller proportion of parents (β = -8.83, t = -4.18, p < .001). Parents' judgments for each target word are shown in Figure 2.

Length of referring expressions. If parents calibrate their referential expressions to their children's linguistic knowledge, they should provide more information to children for whom a simple bare noun (e.g. "leopard") would be insufficient to identify the target. Parents did this in a number of ways: With one or more adjectives (e.g., "the spotted, yellow leopard"), with similes (e.g., "the one that's like a cat"), and with allusions to familiar animal exemplars of the category. In all of these cases, parents would be required to produce more words (see below for further qualitative analyses). Thus, we analyzed the length of parents' referential expressions as a theory-agnostic proxy for informativeness.

We predicted that parents should produce more informative–and thus longer–referring expressions to refer to animals that they thought their children did not know. We divided every trial of the game into two phases: The time before a child selected an animal, and the time following selection until the start of the next trial. We began by testing for coarse tuning: Do parents produce more words to refer to animals that are on average known by fewer children. Figure 3 shows the relationship between the proportion of parents who reported that their child knew each animal and the average number of words produced by parents in the pre-selection phase. As predicted, parents used longer referring expressions for animals that their children were less likely to know. We confirmed this result statistically with a mixed-effects model, predicting the length of referring expressions from phase (before vs. after), appearance number (1st or 2nd), average reported knowledge for each animal, and their interactions (\texttt{log(words+1) $\sim$ phase * appearance * avg_known + (1 | subject) + (1 | animal)}). All of these factors were reliable predictors of amount of words produced: Parents produced fewer words after a referent was selected (β = -0.74, t = -42.51, $p <$ .001), fewer words on an animal's second appearance (β = -0.18, t = -11.69, $p <$ .001), and fewer words if more children were reported to know the animal (β = -0.40, t = -9.44, $p <$ .001). However, the number of words in the post-selection phase was not reduced on the second appearance (β = 0.15, t = 5.99, $p <$ .001) nor by the number of children reported to know the animal (β = 0.31, t = 12.50, $p <$ .001). Further, children's average reported knowledge had a smaller effect on its second appearance in the pre-selection phase (β = 0.11, t = 4.80, $p <$ .001), but again had no effect on the post-selection phase (β = -0.10, t = -2.81, p .005). Thus parents referring expressions reflected a sensitivity to the words that their children were likely to know, especially on the first appearance of each animal. We return to the second appearance in more detail in our analyses of fine-tuning below.

Figure **??** shows the number of words that parents produced to refer to animals that they believe their children know versus those they believe their children do not know–both before their children selected an animal and after. In line with our prediction, parents produced significantly longer referring expressions when talking about animals that they believe their children do not know. However, once the child had selected an animal, the expressions that followed did not differ between known and unknown animals.

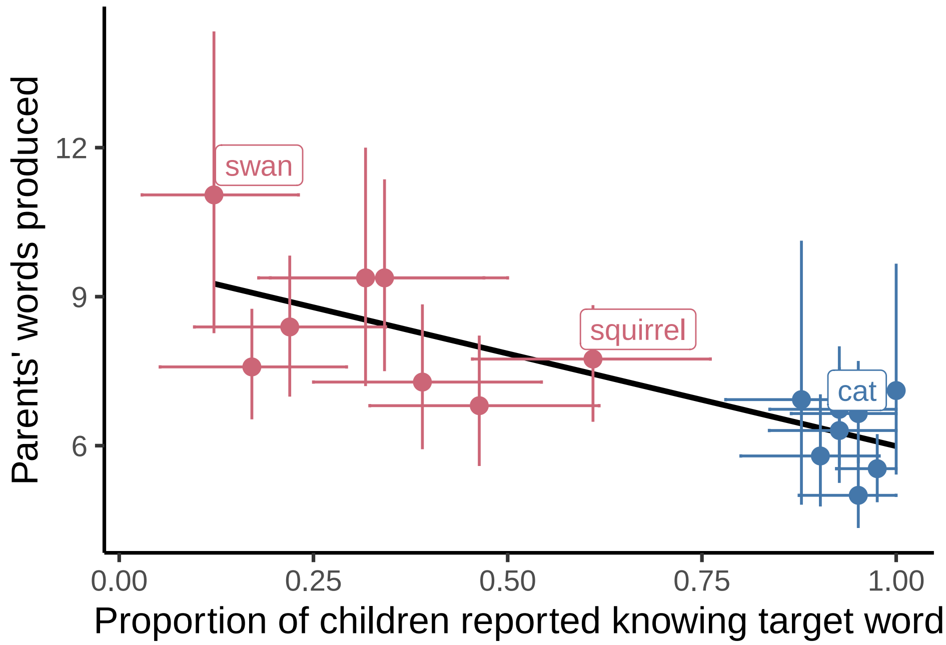
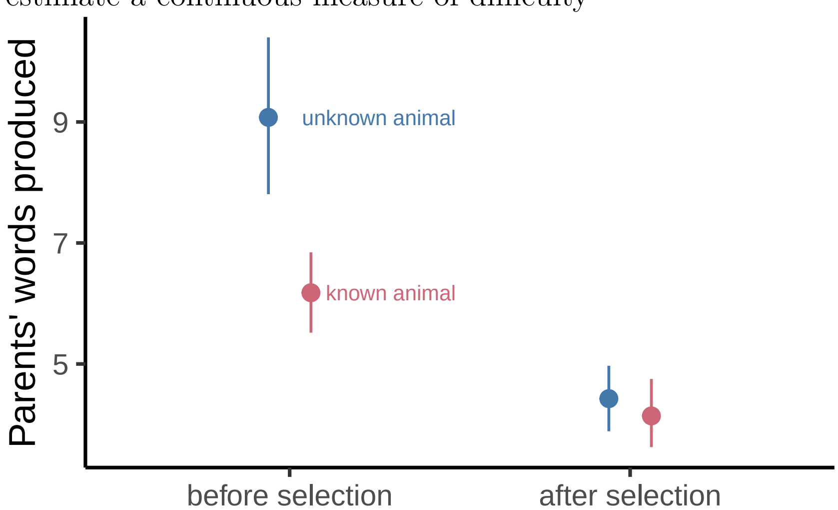


Figure 3. Number of words in parents' referential expressions as a function of the proportion of children reported to know the word for target animal. Points show group averaged proportions, error bars show 95% confidence intervals computed by non-parametric bootstrap.

Although each parent only gave a single bit of information about each animal–whether they thought their child knew it or not–we pooled these judgments across parents to estimate a continuous measure of difficulty



We then tested our second hypothesis: Parents should modify their productions over

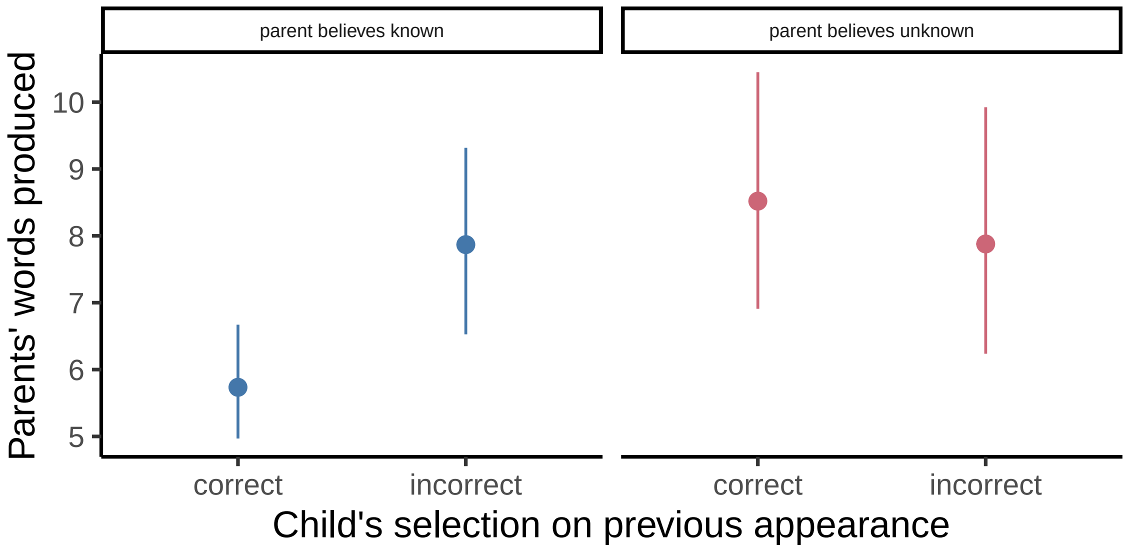


Figure 4. Length of parents' referring expressions on the second appearance of each animal. Points show group averaged proportions; error bars show 95% confidence intervals computed by non-parametric bootstrap.

the course of the experiment as they obtain evidence about their children's knowledge. Because each animal was the target twice, parents could use their children's selection on the first appearance of the animal to inform their referential expressions on the second appearance. Figure 4 shows the length of parents' referring expressions as a function of their prior belief about their children's knowledge and their children's selection on the first appearance of the target animal. As predicted, parents who thought their children knew an animal, but who observed evidence that they didn't (i.e. their children selected the wrong animal), lengthened their referring expressions on its second appearance. Parents who thought their children did not know an animal before the start of the game did not shorten their referring expressions if their children were correct the first time. We cannot say definitively why their referring expressions do not change in length, but one likely explanation is that the references that lead to success the first time were heavily scaffolded and may not even have contained the animal's canonical label (e.g. "the one that looks like a cat" for leopard). We confirmed these results with a mixed effects model predicting length of

term	estimate	t-value	p-value
intercept	3.04	4.33	$<$ .001
length (log)	-1.32	-2.58	.010
unknown	-3.04	-3.18	.001
second appearance	-0.14	-0.85	.395
trial number	0.01	0.88	.380
length * unknown	1.42	2.00	.045

Table 1

Coefficient estimates for a mixed-effects logistic regression predicting children's success in selecting the target animal. The model was specified as `correct ~ log(length) * unknown + appearance + trial + (1|subj) + (1|animal)`.

expressions from parents' prior beliefs, their children's selection on the first trial, and their interaction. We found only the interaction to be significant: References were not reliably longer when parents thought their children did not know the animal (β = 0.30, t = 4.54, p = $<$ .001), nor when the children were incorrect on the previous trial (β = 0.26, t = 3.69, p = $<$ .001, but only when the parent thought their children did not know the animal and their children were incorrect on the previous trial (β = -0.42, t = -4.20, p = $<$ .001).

Children's selections. Overall, children performed significantly above chance for both low AoA and high AoA trials. In our previous analyses, we showed that parents calibrated the length of their referring expressions to their beliefs about their children's knowledge. They did this both in response to their prior beliefs (Figure **??**), and their in-game observations of their children's knowledge (Figure 4). In our final analyses, we asked whether this mattered for children's selections. Are children more likely to succeed in the task when parents provide well calibrated utterances? We asked this question by predicting children's selection trial by trial from a mixed effects logistic regression with fixed effects of parents' prior beliefs about children's knowledge of the target animal, whether the trial was

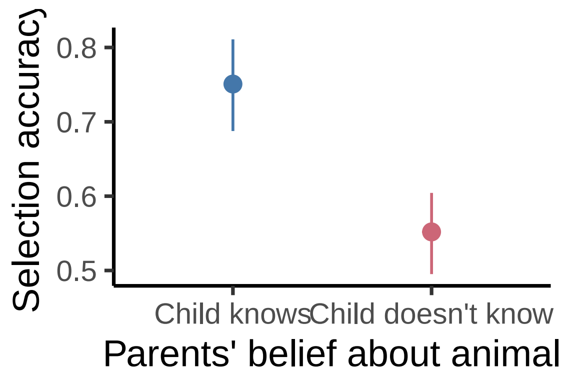


Figure 5. Children's accuracy at selecting both known and unknown animals. Points indicate means, error bars indicate 95% confidence intervals computed by non-parametric bootstrapping.

the first or second appearance of the the target animal, the length of parents' referring expressions, and the interaction of parents' prior beliefs and the length of their expressions, as well as random effects of subject and trial target. Children were more likely to be correct when their parents produced longer references, but only for animals that their parents believed that they did not know. Thus, parents' informative references to unknown animals did appear to be supporting successful communication of the target animal. Table 1 shows coefficient estimates for all parameters.

Qualitative Analysis. We then analyzed the content of parents' utterances by calculating the proportion of trials where parents used the following: canonical labels (e.g. peacock), basic level category labels (e.g. bird), subordinate category labels (e.g. Limelight Larry), descriptors or adjectives, and comparison to other animals (e.g. "the one that looks like a cat"). We predicted that parents would use more descriptors, comparisons, as well as basic level category labels for unfamiliar words. On the other hand, we expected parents to use more canonical labels for familiar animals. We did not have a priori predictions about subordinate category label use, as the decision to include subordinate category labels in qualitative analysis arose upon noticing that parents used them to refer to animals during the game. An overview of results can be seen in Figure 6.

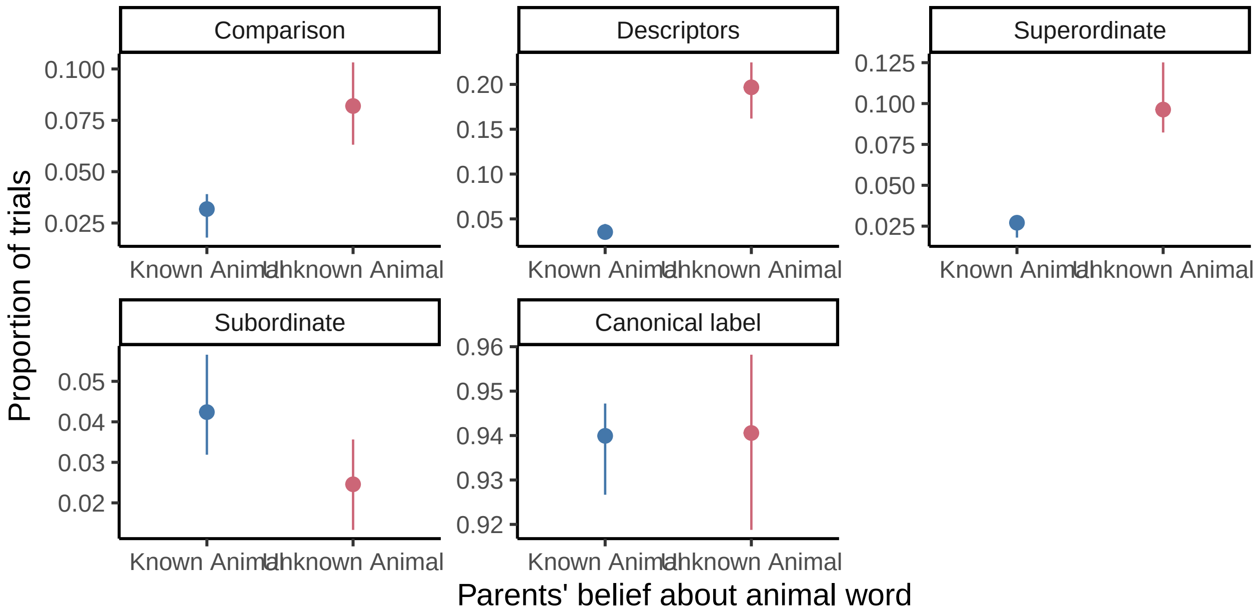


Figure 6. Proportion of trials where parents used canonical labels, descriptors, comparisons, subordinate category labels, and basic category labels. Each panel shows proportions for known and unknown animals.

We looked first at parents' use of canonical labels and subordinate category labels. Our analysis showed no difference in likelihood of using a canonical label in trials with familiar and unfamiliar animals. Instead, parents used canonical labels on most of the trials. However, we found that parents used more subordinate category labels (such as proper nouns) for words that they believe their children knew (β = 2.19, t = 2.36, p = .018).

We then looked at how often parents used descriptors, comparisons, and basic level category labels. Analyses revealed patterns in line with our predictions. Parents used more descriptors (β = -3.02, t = -6.32, $p = <$ .001), comparisons to other animals (β = -2.18, t = -3.01, p = .003), and basic level category labels (β = -3.31, t = -3.97, $p = <$ .001) when they believed their children did not know the target word.

Discussion

Parents have a wealth of knowledge about their kids, including their linguistic development (Fenson et al., 2007). Do they draw on this knowledge when they want to communicate? In a referential communication task, we showed that parents speak differently depending on their beliefs about their children's vocabulary knowledge. Specifically, they produce shorter, less informative expressions to refer to animals that they believe their children know relative to animals that they think their children do not know. Further, parents update their beliefs during the course of the task, producing more informative expressions on the second appearance of an animal they previously thought their children knew if they observed evidence to the contrary (i.e. when children selected the wrong animal). We further found that more informative referring expressions were associated with increased likelihood of successful communication: Children were more likely to correctly select animals whose names they did not know if their parents produced longer utterances to refer to them. We leveraged length as a proxy for informativeness in parents' expressions in the service of quantitative, theory-agnostic predictions. In ongoing work, we are analyzing *how* parents succeed on these trials, and investigating whether different strategies lead to different levels of success.

In general, communicative success was high. Children selected the correct animal at above chance levels, even for targets whose names their parents thought they did not know. Because easy and hard animals appeared on separate trials, children's high accuracy in selecting unfamiliar animals is unlikely to be due to the use of strategies like mutual exclusivity (Markman & Wachtel, 1988). Instead, parents must have produced sufficient information for their children to find the correct target. Taken together with our finding that parents used longer sentences for words they think their children do not know, our results suggest that parents modified their speech as a means to communicate.

Our proposed explanation for these results is that they are produced by a pressure for effective communication: Parents need to produce sufficient information for their children to understand their intended meaning. That is, parents design their utterances for their children's benefit (speaker-design, Jaeger, 2013). It could be instead that these utterances reflect pressure from speaking itself. For example, length of parents' utterances may reflect their difficulty in retrieving certain animal words (MacDonald, 2013). We find this explanation unlikely given that parents were given the target words in written form on their iPad, essentially eliminating retrieval problems (Wingfield, 1968). The fact that parents are using long and short referring expressions depending on their beliefs about children's vocabulary knowledge suggests that they are calibrating to their children.

Parents also modify the *content* of their speech. When talking about animals that they believe their children do not know, parents use more adjectives, comparison to other animals, and basic level category labels. These findings are in line with our predictions, and suggest that parents can use various strategies to ensure successful communication. By providing qualitatively different information, parents can guide their children to the correct animal, even if children do not know the canonical label for that animal. Contrary to our predictions, parents did not use more canonical labels for familiar animals. Parents used canonical labels on most of the trials, regardless of whether they believed their children knew the target word. This could be due to the fact that using the canonical label is not costly for the parents, even if the canonical label itself may be insufficient in guiding the child to select the correct animal. On the other hand, parents did use more subordinate category labels for familiar animals. In our sample, most of the subordinate category labels were proper nouns, such as character names from books or family pets. This shows that parents are not only sensitive to whether their children know a particular animal word, but also the particular animals or characters that their children associate an animal with. It is unlikely that a parent would say "Limelight Larry" instead of "peacock" when speaking to other adults, or even other children. Our findings therefore provide solid evidence that parents are sensitive to their children's knowledge, and can adapt their speech accordingly in order to achieve successful communication.

It is important to note that our current results do not completely rule out the possibility that parents are engaging in pedagogy. Parents may be introducing more information into their referring expressions because they wish to teach their children certain words, which is a potential explanation for why parents adapt the content of their speech when talking about animals their children do not know. The use of adjectives (e.g. "red lobster"), basic level category labels (e.g. "blue bird" for peacock), and comparison to other animals (e.g. "the donkey, it looks like a horse") could all reflect intentions to teach children about different animals. However, within the context of the game, these strategies also serve (at least in part) to facilitate successful communication. In the lobster example, the color "red" is likely a helpful cue for children, and parents may be using adjectives as a way to help children select the correct target quickly.

We would also like to acknowledge that our study used a WEIRD (Henrich, Heine, and Norenzayan (2010)) sample, and thus our results may not fully generalize to other populations. Language development is influenced by a variety of cultural, socio-economic, and environmental factors, and our findings do not account for many of these variables. However, we believe that our work still holds importance when thinking about langauge development in general. Our work focuses on the communicative aspect of language, and we believe that communication is necessary for users of any and all languages. Our study shows that the desire for effective communication can drive parents to modify their spoken language, and we believe this core finding would translate well to other populations, though the specific modifications may vary.

Our work contributes to the current literature on parent-child interaction, and forms the basis for further experimental work examining the influences that parent speech has on children's language development. In line with Masur (1997), our findings provide evidence that parents calibrate speech sensitively to their children's vocabulary knowledge. These results are important in light of previous work suggesting that parent responsiveness and sensitivity shape the way young children learn language (Hoff-Ginsberg & Shatz, 1982; Tamis-LeMonda et al., 2014). Furthermore, we propose that parents are modifying their speech as a means to communicate, and that communicative intent shapes the language environments children experience.

Finally, this study highlights the importance of studying the parent-child pair as a unit, rather than viewing children as isolated learners: both parents and children contribute to the process of language development (Brown, 1977; Hoff-Ginsberg & Shatz, 1982). Focusing on the interactive and communicative nature of language captures a more realistic picture of children's language environments: The input that children receive is not random – it is sensitive to their developmental level.

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