1   Parents Calibrate Speech to Their Children's Vocabulary Knowledge

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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

₂₅   Parents Calibrate Speech to Their Children's Vocabulary Knowledge

₂₆   Variability in input related to variability in output (weisleder, hoff, fernald, hart &

₂₇ risely, etc). Further, not just quanitity but quality (rowe, hoff, etc.)

₂₈   Where does this variability come from? One possibility is about fit–is the input at the

₂₉ right level of developmentally-appropriate complexity. Some evidence for developmental

₃₀ tuning.

₃₁   Important distinction: Coarse tuning (e.g. more words to older kids) vs. fine tuning

₃₂ (e.g. more words specifically about what you don't know). Some indirect tests of that

₃₃ hypothesis with corpus data. Closest thing to a direct test is Masur's work, but even then

₃₄ not quite an experiment.

₃₅   We seek to directly test the fine tuning hypothesis in a referential communication game.

₃₆   The way we speak to children often differs from the way we speak to adults.

₃₇ Child-directed speech (CDS) exists across cultures, and is characterized by higher pitches

₃₈ and more exaggerated enunciations when compared to adult-directed speech (ADS) (Cooper

₃₉ & Aslin, 1990; Grieser & Kuhl, 1988). Not only do children prefer CDS over ADS, CDS is

₄₀ also a better predictor for language learning than overheard ADS (Shneidman, Arroyo,

₄₁ Levine, & Goldin-Meadow, 2013). CDS does not only differ from ADS in prosodic features-

₄₂ the structural qualities of CDS make speech segmentation and word learning easier

₄₃ (Thiessen, Hill, & Saffran, 2005; Yurovsky, Yu, & Smith, 2012). While children live in the

₄₄ same physical environments as adults, their *language environments* contain specific types of

₄₅ input that facilitate early language learning.

₄₆   Children's language environments are not only suited for their abilities; they also

₄₇ change across development. Parents play a role in changing their children's language

₄₈ 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 30 children aged 24 mo.; 5

days to 29 mo.; 20 days ($M = 26$ mo.; 5 days), fourteen of whom were girls. While the

database used for recruitment was intended to reflect the demographic makeup of the local

community, many children in the database are from highly educated, upper-middle class

families. In our sample, seventeen childre were White, and twelve parents had a college

degree or above. We therefore acknowledge that our sample is WEIRD (Westernized,

101 Educated, Industrialized, Rich, and Democratic; Henrich, Heine, and Norenzayan (2010)),

102 and thus our findings may not fully generalize to other populations.

Stimuli

104   Eighteen animal images were selected from the Rossion and Pourtois (2004) image set,

105 which is a colored version of the Snodgrass and Vanderwart (1980) object set. Animals were

106 selected based on estiamtes of their age of acquisition (AoA) for American English learning.

107 To obtain these estimates, we used two sources of information: Parent-report estimates of

108 children's age of acqustion from Wordbank (Frank, Braginsky, Yurovsky, & Marchman,

109 2017), and retrospective self-report estimates of age of acquisition from adults (Kuperman,

110 Stadthagen-Gonzalez, & Brysbaert, 2012, see Supporting Information for details). The age of

111 aquisition of the selected animals ranged from 16 to 32 months. Half of the animals had

112 lower age of acquisition (12-20 months), and the other half had higher age of acquisition

113 (25-31 months). Each trial featured three animals, all from either the low AoA or high AoA

114 category.

115   A modified version of the MacArthur-Bates Communicative Development Inventory

116 (CDI; Fenson et al., 2007), a parent-reported measure of children's vocabulary, was

117 administered before the testing session via an online survey. The selected animal words were

118 embedded among the 85 words in the survey. Two of the animal words–one in the early AOA

119 and one in the late AOA category–were accidentally omitted, so trials for those words were

120 not included in analysis.

121   Each parent-child pair played an interactive game using two iPads. Children were

122 given two warm-up trials to get used to the iPads. The practice and experimental trials

123 began after the warm-up. On each trial, three images of animals were displayed side by side

124 on the child's screen, and a single word appeared on the parent's screen (Figure 1). Parents

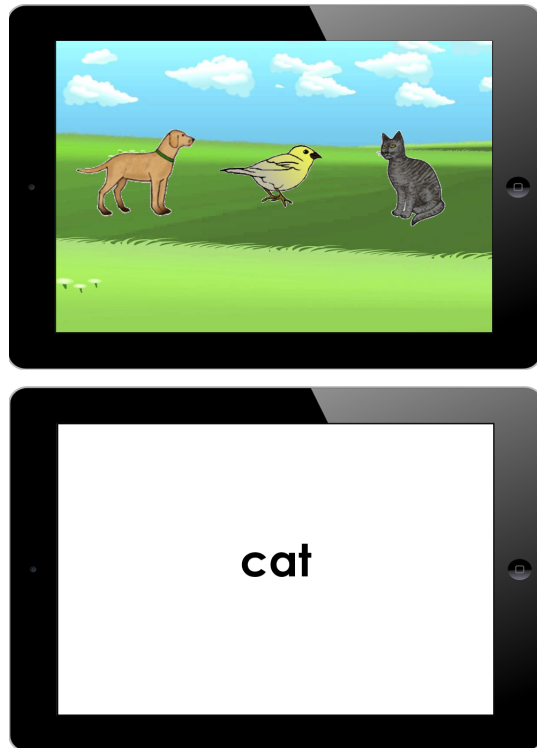125 were instructed to communicate as they normally would with their child, and encourage

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

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 was 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 labesl, 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 94% of parents, and

items in the late AoA category were judged understood by 36%.

The difference between these groups was confirmed statistically with a logistic mixed

effects regression (`correct ~ type + (type | subject) + (1 | word)`). The late AoA

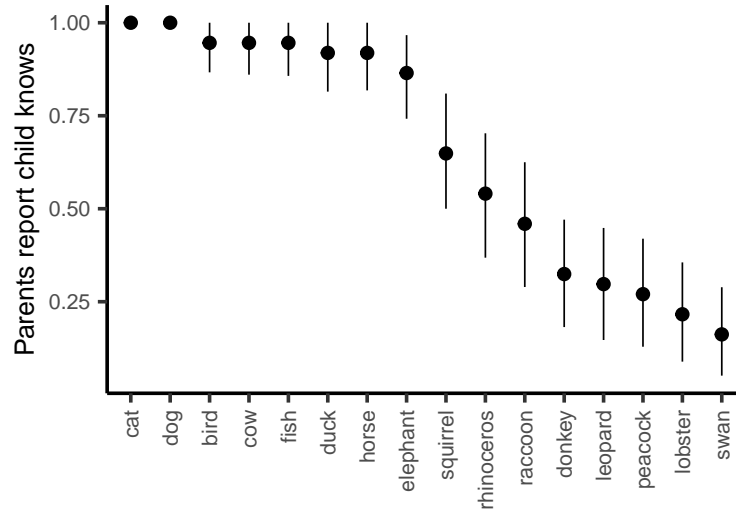items were judged known by a significantly smaller proportion of parents (β = -8.07, t =

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.

163 -3.70, $p < .001$). Parents' judgments for each target word are shown in Figure 2.

164   **Length of referring expressions.**   If parents calibrate their referential expressions

165 to their children's linguistic knowledge, they should provide more information to children for

166 whom a simple bare noun (e.g. "leopard") would be insufficient to identify the target.

167 Parents did this in a number of ways: With one or more adjectives (e.g., "the spotted, yellow

168 leopard"), with similes (e.g., "the one that's like a cat"), and with allusions to familiar

169 animal exemplars of the category. In all of these cases, parents would be required to produce

170 more words. Thus, we analyzed the length of parents' referential expressions as a

171 theory-agnostic proxy for informativeness.

172   We predicted that parents should produce more informative–and thus longer–referring

173 expressions to refer to animals that they thought their children did not know. We divided

174 every trial of the game into phases: The time before a child selected an animal, and the time

175 following selection until the start of the next trial. Figure 3 shows the number of words that

176 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.

We confirmed this result statistically, predicting number of words from a mixed effects model with fixed effects of phase and animal knowledge and their interaction, and random effects of participant and item. In this and all future models, we analyzed the number of words on a log scale as that improved model fit, but results are qualitatively similar when raw number of words was the dependent variable. Phase and the interaction of phase and knowledge were significant: Parents produced fewer words after selection ($\beta = $ -0.60, $t = $ -9.43, $p < .001$), and when the animal was known, ($\beta = $ -0.29, $t = $ -5.28, $p = < .001$), but the change was smaller for known animals ($\beta = 0.20$, $t = 3.44$, $p = .001$). In the remainder of our analyses, we focus on utterances in the pre-selection phase of each trial as the post selection phase did not vary across trial targets.

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 (Figure 2). If parents' referring utterances reflect a sensitivity to this continuous difficulty, the length of their referring expressions should vary smoothly with the difficulty of words. Figure 4 shows this relationship, which was confirmed by a mixed effects model predicting length from fixed effects of difficulty and animal knowledge, and random effects of subject and trial target. Referring expressions were reliably longer for more difficult animals ($\beta = 0.26$, $t = 2.00$, $p = .056$), over and above the increase for unknown animals ($\beta = 0.13$, $t = 1.68$, $p = .106$)

We then tested our second hypothesis: Parents should modify their productions over the course of the experiment as they obtain evidence about their children's knowledge.
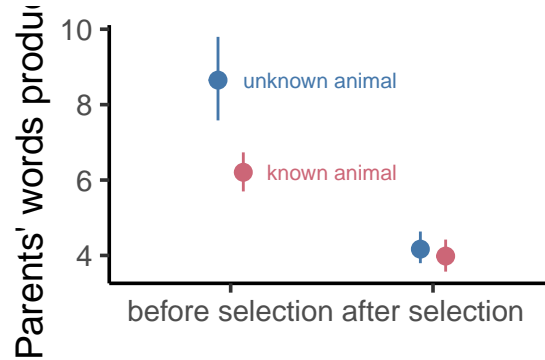
Figure 3. Length of parents' references before and after their child selected a target animal. Points indicate means, error bars indicate 95% confidence intervals computed by non-parametric bootstrapping.

203 Because each animal was the target twice, parents could use their children's selection on the

204 first appearance of the animal to inform their referential expressions on the second

205 appearance. Figure 5 shows the length of parents' referring expressions as a function of their

206 prior belief about their children's knowledge and their children's selection on the first

207 appearance of the target animal. As predicted, parents who thought their children knew an

208 animal, but who observed evidence that they didn't (i.e. their children selected the wrong

209 animal), lengthened their referring expressions on its second appearance. Parents who

210 thought their children did not know an animal before the start of the game did not shorten

211 their referring expressions if their children were correct the first time. We cannot say

212 definitively why their referring expressions do not change in length, but one likely

213 explanation is that the references that lead to success the first time were heavily scaffolded

214 and may not even have contained the animal's canonical label (e.g. "the one that looks like a

215 cat" for leopard). We confirmed these results with a mixed effects model predicting length of

216 expressions from parents' prior beliefs, their children's selection on the first trial, and their

217 interaction. We found only the interaction to be significant: References were not reliably

218 longer when parents thought their children did not know the animal ($\beta = 0.30$, $t = 4.54$, $p =$

219 $< .001$), nor when the children were incorrect on the previous trial ($\beta = 0.26$, $t = 3.69$, $p = <$
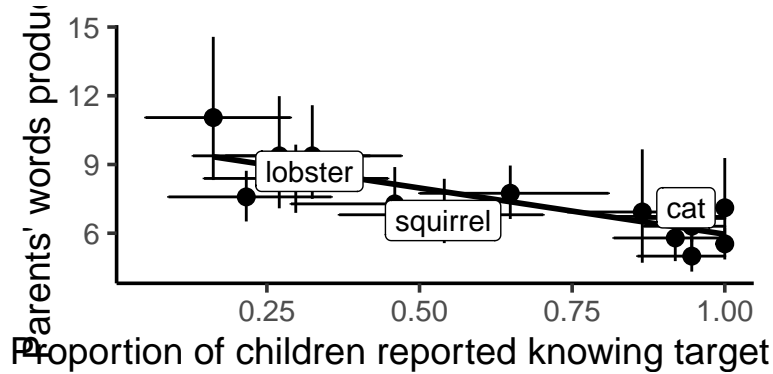
Figure 4. Number of words in parents' referential expressions as a function of the proportion of children reported to know the word for target animal. Points show group averaged proportions, error bars show 95% confidence intervals computed by non-parametric bootstrap.

.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 3), and their in-game observations of their children's knowledge (Figure 5). 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 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
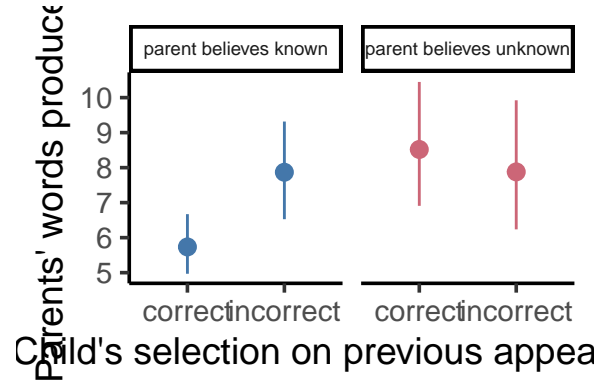
Figure 5. Length of parents' referring expressions on the second appearance of each animal. Points show group averaged proportions; error bars show 95% confidence intervals computed by non-parametric bootstrap.

237 coefficient estimates for all parameters.

238   **Qualitative Analysis.**   We then analyzed the content of parents' utterances by

239 calculating the proportion of trials where parents used the following: canonical labels

240 (e.g. peacock), basic level category labels (e.g. bird), subordinate category labels

241 (e.g. Limelight Larry), descriptors or adjectives, and comparison to other animals (e.g. "the

242 one that looks like a cat"). We predicted that parents would use more descriptors,

243 comparisons, as well as basic level category labels for unfamiliar words. On the other hand,

244 we expected parents to use more canonical labels for familiar animals. We did not have a

245 priori predictions about subordinate category label use, as the decision to include

246 subordinate category labels in qualitative analysis arose upon noticing that parents used

247 them to refer to animals during the game. An overview of results can be seen in Figure 7.

248   We looked first at parents' use of canonical labels and subordinate category labels. Our

249 analysis showed no difference in likelihood of using a canonical label in trials with familiar

250 and unfamiliar animals. Instead, parents used canonical labels on most of the trials.

251 However, we found that parents used more subordinate category labels (such as proper

252 nouns) for words that they believe their children knew ($\beta = 2.19$, $t = 2.36$, $p = .018$).

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)`*.*

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
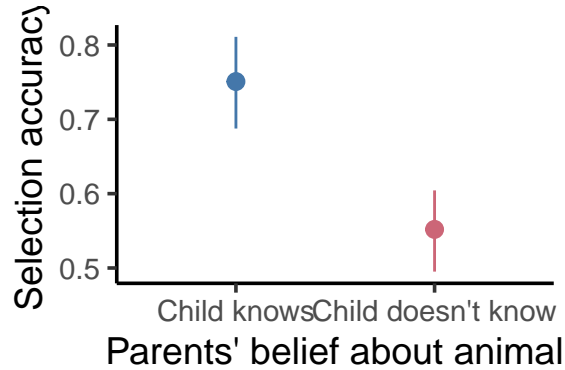
Figure 6. Children's accuracy at selecting both known and unknown animals. Points indicate means, error bars indicate 95% confidence intervals computed by non-parametric bootstrapping.

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.
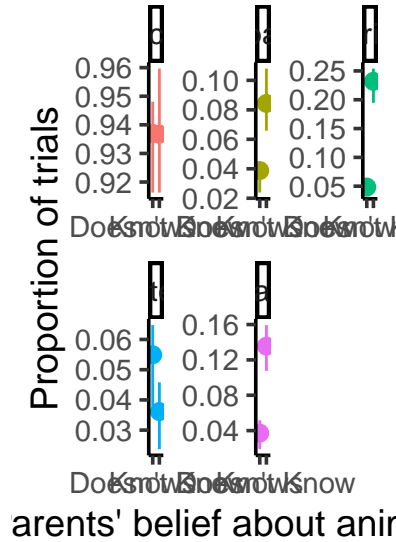
Figure 7. Proportion of trials where parents used canonical labels, descriptors, comparisons, subordinate category labels, and basic category labels. Each panel shows proportions for known and unknown animals.

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

297 qualitatively different information, parents can guide their children to the correct animal,

298 even if children do not know the canonical label for that animal. Contrary to our predictions,

299 parents did not use more canonical labels for familiar animals. Parents used canonical labels

300 on most of the trials, regardless of whether they believed their children knew the target word.

301 This could be due to the fact that using the canonical label is not costly for the parents,

302 even if the canonical label itself may be insufficient in guiding the child to select the correct

303 animal. On the other hand, parents did use more subordinate category labels for familiar

304 animals. In our sample, most of the subordinate category labels were proper nouns, such as

305 character names from books or family pets. This shows that parents are not only sensitive to

306 whether their children know a particular animal word, but also the particular animals or

307 characters that their children associate an animal with. It is unlikely that a parent would say

308 "Limelight Larry" instead of "peacock" when speaking to other adults, or even other children.

309 Our findings therefore provide solid evidence that parents are sensitive to their children's

310 knowledge, and can adapt their speech accordingly in order to achieve successful

311 communication.

312   It is important to note that our current results do not completely rule out the

313 possibility that parents are engaging in pedagogy. Parents may be introducing more

314 information into their referring expressions because they wish to teach their children certain

315 words, which is a potential explanation for why parents adapt the content of their speech

316 when talking about animals their children do not know. The use of adjectives (e.g. "red

317 lobster"), basic level category labels (e.g. "blue bird" for peacock), and comparison to other

318 animals (e.g. "the donkey, it looks like a horse") could all reflect intentions to teach children

319 about different animals. However, within the context of the game, these strategies also serve

320 (at least in part) to facilitate successful communication. In the lobster example, the color

321 "red" is likely a helpful cue for children, and parents may be using adjectives as a way to

322 help children select the correct target quickly.

323 We would also like to acknowledge that our study used a WEIRD (Henrich et al.

324 (2010)) sample, and thus our results may not fully generalize to other populations. Language

325 development is influenced by a variety of cultural, socio-economic, and environmental factors,

326 and our findings do not account for many of these variables. However, we believe that our

327 work still holds importance when thinking about langauge development in general. Our work

328 focuses on the communicative aspect of language, and we believe that communication is

329 necessary for users of any and all languages. Our study shows that the desire for effective

330 communication can drive parents to modify their spoken language, and we believe this core

331 finding would translate well to other populations, though the specific modifications may vary.

332 Our work contributes to the current literature on parent-child interaction, and forms

333 the basis for further experimental work examining the influences that parent speech has on

334 children's language development. In line with Masur (1997), our findings provide evidence

335 that parents calibrate speech sensitively to their children's vocabulary knowledge. These

336 results are important in light of previous work suggesting that parent responsiveness and

337 sensitivity shape the way young children learn language (Hoff-Ginsberg & Shatz, 1982;

338 Tamis-LeMonda et al., 2014). Furthermore, we propose that parents are modifying their

339 speech as a means to communicate, and that communicative intent shapes the language

340 environments children experience.

341 Finally, this study highlights the importance of studying the parent-child pair as a unit,

342 rather than viewing children as isolated learners: both parents and children contribute to the

343 process of language development (Brown, 1977; Hoff-Ginsberg & Shatz, 1982). Focusing on

344 the interactive and communicative nature of language captures a more realistic picture of

345 children's language environments: The input that children receive is not random – it is

346 sensitive to their developmental level.

Acknowledgements

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