₁ Parents fine-tune their speech to children's vocabulary knowledge

₂ XXXXX[1], XXXXX[1], & XXXXX[1,2]

₃ [1] XXXXX

₄ [2] XXXXX

₅ Author Note

₇ Correspondence concerning this article should be addressed to XXXXX, XXXXX.

₈ E-mail: XXXXX

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. How precisely do parents tune their speech to their children's individual language knowledge? To answer this question, we asked parent-child pairs (n=41) to play a reference game in which the parent's goal was to guide their child to select a target animal from a set of three. Parents fine-tuned their referring expressions to their children's knowledge at the lexical level, producing more informative references for animals they thought their children did not know. Further, parents learned about their children's knowledge over the course of the game, and tuned their referring expressions accordingly. Child-directed speech may thus support children's learning not because it is uniformly simplified, but because it is tuned to individual children's language development.

Statement of Relevance

The pace at which children learn language is one of the most impressive feats of early cognitive development. One possible explanation for this rapid pace is that the language caregivers produce is tuned to children's developing linguistic knowledge, maintaining just the right level of complexity to support rapid learning. We present the first experimental evidence of just how precise this tuning is, showing that parents tune not just to children's holistic language development, but their knowledge of individual words. We developed a new method in which we experimentally controlled what parents talked about, but not how they could talk or what they could say, increasing the chance that these results will generalize outside the lab. This work points to the importance of studying the parent-child dyad as a unit instead of focusing on children as isolated learners, both in the domain of language and in social learning more broadly.

³⁴ *Keywords:* parent-child interaction; language development; communication

³⁵ Word count: 749

₃₆   Parents fine-tune their speech to children's vocabulary knowledge

₃₇   In a few short years children master their native language. Undoubtedly, a large share

₃₈ of the credit for this feat is due to powerful learning mechanisms that children bring to their

₃₉ input (Kuhl, 2004; Saffran, Aslin, & Newport, 1996). However, a share of the credit may also

₄₀ be due to the linguistic input itself: Individual differences in the quantity and quality of the

₄₁ language children hear are associated with differences in language learning (Hart & Risley,

₄₂ 1995; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Rowe, 2012). Further,

₄₃ these associations are driven by speech directed to children. Differences in overheard speech

₄₄ do not predict differences in language learning, even in communities where child-directed

₄₅ speech is relatively rare (Romeo et al., 2018; Shneidman & Goldin-Meadow, 2012; Weisleder

₄₆ & Fernald, 2013).

₄₇   Child-directed speech differs from adult-directed speech along many dimensions, most

₄₈ of which are characterized by simplification (Snow, 1972). But, the amount of simplification

₄₉ changes over development, i.e. parents direct longer and more complex utterances to older

₅₀ children (Huttenlocher et al., 2010). Child-directed speech may thus facilitate learning not

₅₁ because it is uniformly simpler, but because it is adaptive, tuned to the right level of

₅₂ complexity for children's ongoing language development (Snow, 1972; Vygotsky, 1978). How

₅₃ precisely tuned is child-directed speech?

₅₄   One possibility is that tuning is *coarse*: Caregivers could tune the complexity of their

₅₅ speech generally, using a holistic sense of their children's developing linguistic abilities. This

₅₆ accords evidence showing that parents tune their utterance lengths, articulation of vowels,

₅₇ and diversity of clauses to children age (Bernstein Ratner, 1984; Huttenlocher et al., 2010;

₅₈ Moerk, 1976). However, linguistic tuning would be an even more powerful scaffold for

₅₉ learning if parents *fine-tuned* their speech, taking into account not only children's global

₆₀ linguistic development, but their specific knowledge of smaller units of language, such as

₆₁ lexical items (Bruner, 1983). To date, the only evidence for fine-tuning comes from two

62 observational studies, one showing that parents are more likely to provide their child with

63 labels for novel as compared to familiar toys (Masur, 1997), and the second showing that one

64 child's caregivers produce their shortest utterances containing a particular word just before

65 the child first produces that word (Roy, Frank, & Roy, 2009).

66   Here, we present the first *experimental* evidence for fine-tuning. Children and their

67 parents played a reference game in which the parent's goal was to guide their child to select

68 a target animal from a set of three. Parents tuned the amount of information in their

69 utterances not just to the average difficulty of each animal word, but to their prior estimates

70 of their individual child's knowledge of that animal. Further, parents sensitively adapted

71 over the course of the game, providing more information on subsequent trials when they

72 discovered that their child did not know an animal. Together, these results show that

73 parents leverage their knowledge of their children's language development to fine-tune the

74 linguistic information they provide.

Method

Participants

77   Toddlers (aged 2-2.5 years) and their parents were recruited from a database of families

78 in the local community or approached on the floor of a local science museum in order to

79 achieve a planned sample of 40 parent-child dyads. Because our method was novel, we chose

80 a sample size that would give us 95% power to detect a medium-sized effect ($d=.6$)

81 within-subjects and rounded up to the nearest multiple of 10. A total of 48 parent-child

82 pairs were recruited, but data from 7 pairs were dropped from analysis because of failure to

83 complete the experiment as designed. The final sample consisted of 41 children aged 24 mo.;

84 5 days to 29 mo.; 20 days ($M = 26$ mo.; 0 days), 21 of whom were girls.

85   In our recruitment, we made an effort to sample children from a variety of racial and

86 socio-economic groups. Our final sample was roughly representative of the racial composition

87 of the Chicago Area and the US more broadly (56% White, 27% Black, 8% Hispanic).

88 However, our sample was significantly more educated than the broader community (85% of

89 mothers had a College or Graduate Degree).

Stimuli

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

92 a colorized version of the Snodgrass and Vanderwart (1980) object set. Animals were

93 selected based on estimates of their age of acquisition (AoA) for American English learners.

94 To obtain these estimates, we used two sources of information: parent-report estimates of

95 children's age of acquisition from Wordbank (Frank, Braginsky, Yurovsky, & Marchman,

96 2017), and retrospective self-report estimates of AoA from adults (Kuperman,

97 Stadthagen-Gonzalez, & Brysbaert, 2012, see Supplemental Materials for details). The AoA

98 of the selected animals ranged from 15 to 32 months. Half of the animals were chosen to have

99 an early age of acquisition (15-23 months), and the other half were chosen to have a late age

100 of acquisition (25-32 months). Each trial featured three animals, all from either the early

101 AoA or late AoA category. This separation was designed to lower the likelihood that children

102 could use knowledge of early AoA animals to infer the correct target on late AoA trials.

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

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

105 was administered before the testing session via an online survey. The selected animal words

106 were added to the standard words, producing a the 85 word survey. Two of the animal

107 words–one in the early AOA (pig) and one in the late AOA category (rooster)–were

108 accidentally omitted, so trials for those words were not included in analyses as we could not

109 obtain individual-level estimates of children's knowledge.

Figure 1. A parent-child dyad playing the reference game. On each trial, the parent's goal was to use language to communicate to their child which animal to choose.

Design and Procedure

Each parent-child pair played an interactive reference game using two iPads (Figure 1). Children began with two warm-up trials in which they tapped on circles that appeared on the iPads. Following these warm-up trials, children and their parents moved on to practice and then experimental trials. 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. Parents were instructed to communicate as they normally would with their child, and to encourage their child to choose the object corresponding to the word on their screen. The child was instructed to listen to their parent for cues. Once the child tapped an animal, 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.

Data analysis

Our primary quantity of interest was the amount of information that parents provided in each of their utterances. To approximate this, we measured the length of parents' referring expressions–the number of words they produced on each trial before their child selected an animal. Length is an imperfect proxy for information, but it is easy to quantify and theory-agnostic. Because utterance length is highly right-skewed (i.e. most utterances are short), we log-transformed length in all analyses. However, to facilitate interpretability, we show raw utterance length in our figures. Subsequently, utterances were manually coded for the following: (1) Use of an animal's canonical label (e.g., "leopard"), (2) Use of a descriptor (e.g., "spotted"), (3) Use of a comparison (e.g., "like a cat"), (4) Use of a subordinate category label (e.g., "Limelight Larry" for peacock), and (5) Use of a superordinate level category label (e.g., "bird" for peacock). Parent utterances irrelevant to the game (e.g. asking the child to sit down) were not analyzed. Children's utterances were coded when audible, but were not analyzed.

Our second source of data was the vocabulary questionnaire that parents filled out prior to participation. Parents indicated whether their child produced each of the 85 words on the survey. In addition to analyzing parents' judgments for the animals in the task, we also computed the total number of words judged to be known for each child as a proxy for total vocabulary.

All of our analyses were done using mixed-effects models. In all cases we began with maximal random effects structures and pruned random effects until the models converged. We removed interaction terms before removing main effects, and opted to keep the most-theory relevant random effects when only a subset of main effects could be kept. For clarity, we present only the key findings and statistics here, but full model details can be found in the Supplemental Materials.

¹⁴⁹ <center>**Results**</center>

¹⁵⁰ We begin by confirming that our a priori divisions of animals into early and late age of

¹⁵¹ acquisition in the study design were reflected in parents' survey judgments, and that children

¹⁵² were able to follow parents' references to select the correct target animal on each trial. After

¹⁵³ this, we show that parents fine-tune their referring expressions, producing more information

¹⁵⁴ in their references to animals that they think their individual children do not know. Further,

¹⁵⁵ parents update their tuning over the course of the experiment, producing more information

¹⁵⁶ on subsequent references to animals they thought they children knew but observed evidence

¹⁵⁷ to the contrary (i.e. children made an incorrect selection).

¹⁵⁸ **Target animal difficulty**

¹⁵⁹ We first confirm that the early age of acquisition (AoA) animals were more likely to be

¹⁶⁰ marked "known" by the parents of children in our studies. As predicted, parents judged that

¹⁶¹ their children knew 94% of the animals in the early AoA category, and 33% of the animals in

¹⁶² the late AoA category, which were reliably different from each-other (β = -7.25, $p <$ .001).

¹⁶³ Parents' judgments for each target word are shown in the Supplemental Materials.

¹⁶⁴ **Selection accuracy**

¹⁶⁵ On the whole, parents communicated effectively with their children, such that children

¹⁶⁶ selected the correct target on 69.05% of trials, reliably greater than would be expected by

¹⁶⁷ chance (33%, β = 2.07, $p <$ .001). Children were above chance both for animals that parents

¹⁶⁸ thought they knew (M = 75.08%, β = 2.61, $p <$ .001), and for animals that parents thought

¹⁶⁹ their children did not know (M = 55.19%, β = 1.23, $p <$ .001). Thus, parents successfully

¹⁷⁰ communicated the target referent to children, even when parents thought their children did

¹⁷¹ not know the name for the animal at the start of the game.

¹⁷² Was this accuracy driven by children's knowledge or parents' referential expressions?

¹⁷³ To answer this question, we fit a mixed-effects logistic regression predicting children's

174 accuracy on each trial from children's total estimated vocabulary, knowledge of the target

175 animal, and the (log) length of parents' expressions. We found that children with bigger

176 vocabularies were more accurate in general ($\beta = 0.40$, $p = .001$), and that children were less

177 accurate for animals whose names they did not know ($\beta = $ -1.86, $p < .001$). Longer

178 referential expressions were associated with lower accuracy for known animals ($\beta = $ -0.40,

179 $p = .007$), but greater accuracy for unknown animals ($\beta = 0.46$, $p = .025$).

180   Thus, longer referential expressions were associated with more successful

181 communication for animals that children did not know, but were unhelpful for animals that

182 they did know. We next ask whether parents tuned the lengths of their utterances

183 appropriately, producing longer expressions for unknown animals.

184 **Tuning**

185   If parents calibrate their referring expressions to their children's linguistic knowledge,

186 they should provide more information to children for whom a simple bare noun

187 (e.g. "leopard") would be insufficient to identify the target. Parents did this in a number of

188 ways: with one or more adjectives (e.g. "the spotted, yellow leopard"), with similes (e.g. "the

189 one that's like a cat"), and with allusions to familiar animal exemplars of the category

190 (e.g. "pick Midnight"). In many of these cases, parents would be required to produce more

191 words (see below for further qualitative analyses). Thus, we first analyzed the (log) length of

192 parents' referring expressions as a proxy for informativeness.

193   When do parents produce longer referring expressions? One possibility is that parents

194 tune at the coarsest level, using more words when speaking to children with smaller

195 vocabularies. This was not the case–the total number of words parents thought their

196 children knew did not reliably affect the length of their referring expressions ($\beta = $ -0.02, $p = $

197 .595). A second possibility is that parents have a sense for how difficult each animal is in

198 general, and tune coarsely to this. Our analyses confirmed this coarse tuning: Parents said
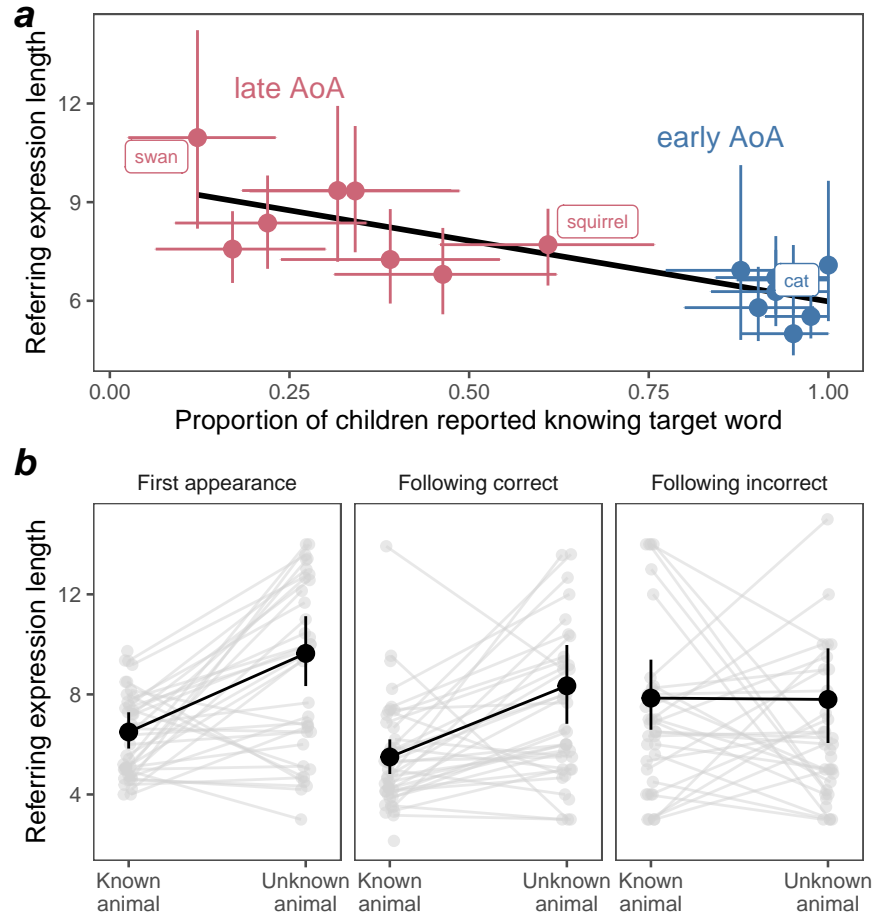
Figure 2. (A) Parents produced longer referring expressions to communicate about animals that children were generally less likely to know. (B) Parents produced longer referring expressions for words that they thought their child did not know (left panel). When children selected correctly in response to these expressions, parents continued to produce longer expressions for animals they thought their children did not know. However, if parents thought their child knew an animal, and they chose incorrectly, parents lengthened produced longer expressions on its second appearance (right 2 panels). Gray points and lines represent individual participants, colored points and lines show group averaged proportions; error bars show 95% confidence intervals computed by non-parametric bootstrap.

reliably fewer words for animals that more children were reported to know (β = -0.17, p = .034; Figure 2A). Finally, parents could fine-tune their referential expressions to their children's individual knowledge, over and above the average difficulty of each animal. Our analyses supported this conclusion: Parents used reliably fewer words to refer to animals that they thought their individual child knew (β = 0.25, p = .003; Figure 2B). Thus parents fine-tuned the amount of information in their referential expressions, calibrating the amount of information they provided to their children's knowledge, even after accounting for the average difficulty of the target animal.

In addition, because each animal appeared as a target twice, we asked whether parents tuned their referential expressions over successive appearances. We found that parents used fewer words on the second appearance of each animal (β = -0.08, p = .044), but that the difference in utterance length between known and unknown animals was smaller on their second appearance (β = -0.14, p < .001). Why might that be? One possibility is that parents obtain information from the first appearance of each animal: they may have thought their child knew "leopard," but discovered from their incorrect choice that they did not. If so, they might produce provide more information the second time around.

To test this prediction, we fit a model predicting the (log) length of parents' referring expressions on the second appearance of each animal from success on first appearance, whether they thought their child knew the animal prior to the experiment, and their interaction. Parents produced marginally shorter expressions when children were incorrect on the first appearance of each animal (β = -0.15, p = .091), and shorter referring expressions for animals that they believed their child knew (β = -0.35, p = .001). However, they produced longer referring expressions following an incorrect response for animals they thought their children knew (β = 0.48, p < .001). Thus, when parents thought their children knew an animal, but then observed evidence to the contrary, they provided more information in their referring expressions for children to make the correct selection the second time.

225 Importantly, this same pattern was not found in unknown animals–parents' referring

226 expressions did not differ in length for known and unknown animals when children had

227 incorrectly selected on the first appearance (Figure 2B).

228   Together, these two sets of analyses suggest that parents tune their referring

229 expressions not just coarsely to how much language their children generally know, nor their

230 knowledge about how hard animal words are on average, but finely to their beliefs about

231 their individuals children's knowledge of specific lexical items. Further, when they discover

232 that they have incorrect beliefs about their children's knowledge, they update these beliefs in

233 real-time and leverage them on subsequent references to the same lexical item.

Content of referring expressions

235   Parents produced reliably longer referring expressions when trying to communicate

236 about animals that they thought their children did not know. In the analyses presented so

237 far, we used length as a theory-agnostic, quantitative measure of information. *How* did

238 parents successfully refer to animals that their children did not know? As a post-hoc

239 descriptive analysis, we coded five qualitative features of referring expressions: (1) Use of the

240 animal's canonical label (e.g., "leopard"), (2) Use of a descriptor (e.g., "spotted"), (3) Use of

241 a comparison (e.g., "like a cat"), (4) Use of a subordinate category label (e.g., "Limelight

242 Larry" for peacock), and (5) Use of a superordinate level category label (e.g., "bird" for

243 peacock). Because the rates of usage of each of these kinds of reference varied widely

244 (e.g. canonical labels were used on 94.51% of trials, but subordinates were used on 1.21% of

245 trials), we fit a logistic mixed effects model separately for each reference kind, estimating

246 whether it would be used on each trial from whether the parent thought their child knew the

247 animal.

248   Canonical labels were used on almost all trials, and did not differ in frequency between

249 unknown ($M = 94.68\%$) and known ($M = 93.48\%$) animals ($\beta = 0.43$, $p = .216$).

Comparisons were used reliably more for unknown ($M = 4.65\%$) than for known animals,

($M = 2.75\%$, $\beta = 2.29$, $p = .001$), as were descriptors (known $M = 0.70\%$, unknown $M = 17.33\%$, $\beta = 3.09$, $p < .001$) and superordinate category labels (known $M = 0.15\%$, unknown $M = 7.02\%$, $\beta = 3.01$, $p = .026$). Subordinates were used less for unknown ($M = 0.35\%$) than for known animals ($M = 2.57\%$, $\beta = -2.19$, $p = .025$). Thus, parents used a variety of strategies to refer to animals that children did not understand, but the use of descriptors was the most prominent. These descriptors are particularly apt to facilitate children's learning, connecting parents' fine-tuning for reference with their children's language acquisition.

Discussion

Parents have a wealth of knowledge about their children's linguistic development (Fenson et al., 2007). We show that parents draw on this knowledge to tune speech to their children in three ways: (1) they produce longer, more informative referring expressions for later-learned animals, (2) over and above this coarse tuning, parents' tune information to their individual children's knowledge of specific animals, and (3) when children do not know an animal that parents thought they did, parents' subsequent references reflect this updated belief. Further, 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. Finally, we found that references to unknown animals were rich with descriptors and comparisons, helping children select the correct animal and potentially serving as a source of learning input.

These data are consistent with a strong form of the linguistic tuning hypothesis, in which parents fine-tune the information in their speech to children's language knowledge at the individual-word level. Why should this happen? Although parents' speech to children is unlikely to reflect a goal to teach, it is nonetheless goal-oriented: parents want to communicate successfully (Bruner, 1983). Fortunately, learning may piggyback on this

optimization because of the inherent synergy between communication and learning–it is easier to learn from input that you understand (Yurovsky, 2018). Children bring powerful learning mechanisms to language acquisition, but these mechanisms are supported by an ecological niche designed for their success.

Acknowledgements

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