

Child language input does not reflect word frequency: Typical and atypical feature description across development

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Abstract

Language provides children a powerful source of information about the world. From language alone, simple distributional learning models can recover enough information to perform comparably to non-native college applicants on the TOEFL (Landauer & Dumais, 1997). Blind children learn the same kinds of relationships among visual categories as sighted children, without any of the relevant visual input (Landau & Gleitman, 1985). However, language does not perfectly reflect the world: the most typical features of natural kinds may often go unremarked. For instance, adults rarely describe the color of an orange carrot, as world knowledge makes this description redundant. Given children's nascent world knowledge, does parents' speech to children follow this pattern? From longitudinal corpus data of parent-child communication (Goldin-Meadow et al., 2014) between 14–58 months, we extracted usage data for 684 high-frequency concrete nouns and co-occurring adjectives. Independent raters coded the typicality of over 2,000 unique adjective–noun pairs on a 7-point Likert scale. If language statistics reflect world statistics, description should be dominated by the typical (strong negative skew); however, across all ages, we see descriptors concentrated in the atypical range (positive skewness = 0.65). However, parents were reliably more likely to use typical descriptors when talking to younger compared with older children. Overall, child language input reflects notable more than typical features, but increased description of typical features early in development may provide a foothold for young learners.

Keywords: language input, language acquisition, child-directed speech

Children learn a tremendous amount about the structure of the world around them in just a few short years, from the rules that govern the movement of physical objects to the hierarchical structure of natural categories and even relational structures among social and cultural groups (Baillargeon, 1994; Legare & Harris, 2016; Rogers & McClelland, 2004). Where does the information for this rapid acquisition come from? Undoubtedly, a sizeable component comes from direct experience observing and interacting with the world (Sloutsky & Fisher, 2004; Stahl & Feigenson, 2015). But another important source of information comes from the language people use to talk about the world (Landauer & Dumais, 1997; Rhodes, Leslie, & Tworek, 2012). For many of the things children learn about—like the roundness of the earth—the information must come from language (Harris & Koenig, 2006). How similar is the information available from children's direct experience to the information available in the language children hear?

Two lines of work suggest that they may be surprisingly similar. One compelling area of work is the comparison

of semantic structures learned by congenitally blind children to those of their sighted peers. In several domains that would at first blush rely heavily on visual information, such as color terms or verbs of visual perception (e.g. *look*, *see*), blind children's semantic similarity judgments are quite similar to those of sighted children (Landau, Gleitman, & Landau, 2009). Further, blind adults' judgments of visual perception verbs are sensitive to highly detailed information like variation in intensity (e.g. *blaze* vs. *glow*), just like sighted adults (Bedny, Koster-Hale, Elli, Yazzolino, & Saxe, 2019). A second line of evidence supporting the similarity of information in perception and language is the broad success of statistical models trained on language alone in approximating human judgments across a variety of domains (Devlin, Chang, Lee, & Toutanova, 2018; Landauer & Dumais, 1997; Mikolov, Sutskever, Chen, Corrado, & Dean, 2013). Even more compellingly, models trained on both linguistic usage and perceptual features for some words can infer the perceptual features of linguistically related words entirely from the covariation of language and perception (Johns & Jones, 2012).

Still, there is reason to believe that some semantic features may be harder to learn from language than these data suggest. While the co-occurrence structure of language may provide strong clues that carrots are like tomatoes, carrots are vegetables, and carrots are eaten for dinner, they may provide very little evidence that carrots are orange (Willits, Sussman, & Amato, 2008). This is because people rarely use language merely to provide running commentary on the world around them. Instead, we use language to talk about things we find interesting—things that are surprising, exciting, or otherwise divergent from our conversational partners' expectations (Grice, 1975).

Thus, speakers are informative in relation to common knowledge with their conversational partner and available information in the environment, not redundant with these other sources of knowledge. Communication tasks in the lab largely bolster this claim, finding that people avoid being over- or under-informative when they speak (Mangold & Pobel, 1988; MORE CITES) and interpret others' speech as if they are doing the same (CITES). In particular, speakers are informative in relation to both the context of objects in the environment and the typical features of those objects (Mitchell et al., 2013; Westerbeek et al., 2015; Rubio-Fernandez, 2016). While speakers overwhelmingly refer to

an object that is typical of its category with a bare noun—e.g., calling a yellow banana “a banana”—they often describe more about the object’s features when they are atypical, rarely referring to a green or blue banana without specifying its color. Listeners are similarly affected by color description, expecting a color adjective to be used when an object’s color is atypical (Sedivy, 2003).

For things like carrots—that children learn about both from perception and from language—this issue may be resolved by integrating both sources of information: Likely almost all of the carrots they see are orange even if no one comments on them. But for things for which they lack perceptual access—zoo animals, other social groups, and so on—the structure of language alone may lead them to have distorted categories. This may be especially problematic because children’s understanding of the pragmatics of adjective use change significantly over development (Horowitz & Frank, 2016).

Should we expect children’s categories to be biased in this way, with typical features underrepresented and atypical features overrepresented? We examine the typicality of adjectives in a large, diverse corpus of parent-child interactions recorded in children’s homes to ask whether parents talking to their children—just like adults speaking and writing—tend to use adjectives predominantly to mark atypical features. We find that they do: parents and children overwhelmingly choose to mention atypical rather than typical features. However, we also find that parents use adjectives differently over the course of children’s development, noting typical features more often to younger children. We then ask whether the co-occurrence structure of language nonetheless captures typicality information, and find that relatively little of it is represented. Thus, children must either have distorted representations of categories learned only through language or else learn typicality through other means.

Adjective typicality

In order to determine whether parents use adjectives mostly to mark atypical features of categories, we analyzed caregiver speech from a large corpus of parent-child interactions recorded in the home. We extracted all adjective-noun combinations for concrete nouns, and asked a sample of Amazon Mechanical Turkers to judge how typical the property described by each adjective was for the noun it modified. We then examined both the broad features of this typicality distribution and how it changed over development.

Corpus

We used data from the Language Development Project—a large-scale, longitudinal corpus of parent-child interactions recorded in children’s homes. Families were recruited to be representative of the Chicagoland area in both socioeconomic and racial composition (Goldin-Meadow et al., 2014). Recordings were taken in the home every 4-months from when the child was 14-months-old until they were 58-months-old, resulting in 12 timepoints. Each recording was of a 90-minute session in which parents and children were

free to behave as they liked and interact as much or as little as they liked.

Our sample consistend of all N typically-developing children and their parents, who were recorded for at least M timepoints. Together, this resulted in a total of 828,392 distinct parent utterances. **SHOULD DO THIS IN CODE**

Stimulus Selection

From these utterances, we extract all of the nouns (using part of speech tags—**MANUAL? AUTOMATIC**). Because of our interest in the change in speech of development, we considered only nouns that appeared at least once every 3 sessions (i.e. per developmental year). This yielded a set of some 2,000 potential target nouns (**how many did we lose?**).

We selected from the corpus all N utterances containing any of these nouns and any word tagged as an adjective. We considered for analysis all adjective-noun pairs that occurred in any utterance (i.e. utterances with one noun and three adjectives were coded as three pairs). This set contained a number of high-frequency idiomatic pairs whose typicality was difficult to classify (e.g., “good”–“job”; “little”–“bit”). To resolve this issue, we used human judgments of words’ concreteness to identify and exclude candidate idioms (Brybaert, Warriner, & Kuperman, 2014). We retained for analysis only pairs where both the adjective and noun were in the top 25% of the concreteness ratings. **GIVE EXAMPLES, SAY HOW MANY**. Finally, all pairs were given to 7 human coders to judge whether the pair was “incoherent or unrelated” and we thus excluded a further XXX pairs from the sample (e.g., incoherent pairs such as “wet” – “brown”, and presumably errorfully coded pairs such as “orange” – “orange”).

Thus, our final sample included 2,220 unique adjective-noun pairs drawn from over 6,000 utterances. The pairs were combinations of 684 distinct concrete nouns and 118 distinct concrete adjectives. We compiled these pairs and collected human judgments on Amazon Mechanical Turk for each pair, as described below. Table ?? contains example utterances from the final set and typicality judgments from our human raters.

Participants

Each participant rated 20 pairs, and each pair was rated by four participants; we used Dallinger [CITE], a tool for automating complex recruitment on Amazon Mechanical Turk, to balance recruitment. Overall, we recruited 444 participants to rate 2200 adjective–noun pairs. After exclusions using an attention check, we retained 8580 judgments, with each adjective–noun pair retaining at least two judgments.

Design and Procedure

To evaluate the typicality of the adjective–noun pairs pulled from the corpus, we asked participants on Amazon Mechanical Turk to rate each pair. Participants were presented with a question of the form “How common is it for a cow to be a brown cow?” and asked to provide a rating on a seven-point

utterance	pair	rating 1	rating 2	rating 3	rating 4	mean typicality
especially with wooden shoes	wooden-shoe	2	2	3	2	2.75
some of our green bananas too	green-banana	4	3	5	3	3.75
are bananas yellow?	yellow-banana	5	5	7	6	5.75

Table 1: Sample typicality ratings from 4 human coders for three adjective-noun pairs drawn from the corpus.

scale: (1) never, (2) rarely, (3) sometimes, (4) about half the time, (5) often, (6) almost always, (7) always.

Results

If description in child-directed speech mirrors adult-directed speech, we should see that caregiver description is dominated by modifiers that are sometimes true of the noun they modify. If instead child-directed speech privileges redundant or assumed information, caregiver description should yield a distinct distribution dominated by highly typical modifiers. As can be seen in figure 1, there is remarkable developmental consistency: caregiver description largely focuses on features that are only sometimes true of the concept.

Developmental Consistency. A mixed effects model predicting typicality from usage confirms that caregiver speech is significantly biased toward description of atypical speech ($B \text{ XXX}, p < \text{YYY}$). The full mixed effects model included random effects of noun and rater, specified as follows `lmer(typicality ~ log(age) + (1|noun) + (1|rater)` using an offset of 4 which is the midpoint of our scale. Rather than focusing on typical information, caregiver language tends on average be about less typical features (i.e. ‘sometimes’, ‘rarely’ or ‘never’).

Examining usage data as a function of typicality (see figure 1), we see evidence of a positive skew (0.65). Data from every time point from 14-58 months seems to show a similar pattern (skews 0.23 - 0.82). These skews provide further evidence that the the bulk of caregiver language reflects lower-typicality adjective-noun pairs.

Our mixed effects model also yields some evidence of developmental change. There is a negative effect of age on typicality ($B \text{ XXX}, p < \text{YYY}$), suggesting that children’s language environments become increasingly focused on atypical features as they get older. This result is discussed further below.

Adult to adult Speech. Next, we briefly confirm that adult to adult speech shows the similar usage pattern using an identical analysis framework on usage data from the Corpus of Contemporary American English (COCA). Using the set of adjective-noun pairs for which we have judgments from our analysis of caregiver speech, we repeat our analysis of usage frequencies for a set of 1,357 distinct adjective-noun pairs.

As predicted, an identical mixed effects model predicting typicality from usage shows that adult-directed speech speech is significantly biased toward description of atypical features ($B \text{ XXX}, p < \text{YYY}$). ADS also shows a similar a positive skew (0.68), such that the bulk of language reflects adjective-

noun pairs rated < 4 on typicality (i.e. ‘sometimes’, ‘rarely’ or ‘never’).

The usage distributions in adult-directed speech seem qualitatively similar to the distributions we found in child-directed speech. In sum, these data suggest that even when talking with very young children, caregiver speech structures information similarly to adult-directed speech.

The difference of settings makes it difficult to compare these data directly with our data from the Language Development Project corpus. Four of the COCA datasets are drawn from written texts, which puts in place distinct language pressures and removes visual common ground. While there is one subset of the corpus drawn from spoken data, those utterances come from TV and radio programs. All of these settings are likely quite different environments for language than the naturalistic in-home setting that our Language Development Project corpus draws from. In light of these differences, any observed similarity in usage seems remarkable.

Child Speech. What kind of information is contained in children’s own speech? By analyzing children’s own utterances, we can determine when children come to use description in a way that looks like caregiver speech. Are children mirroring adult-like uses of description even from a young age, or are they choosing to describe more typical features of the world?

The Language Development Corpus contains 442,048 child utterances. Using the set of adjective-noun pairs for which we have judgments from our analysis of caregiver speech, we repeat our analysis on usage data for a set of 533 distinct adjective-noun pairs.

While preliminary, an identical mixed effects model predicting typicality from usage shows that children’s speech is significantly biased toward description of atypical features ($B \text{ XXX}, p < \text{YYY}$). Mirroring caregiver and adult-adult speech, children’s productions show a positive skew (0.61, compare with skewness = 0.65 seen in the adults), such that the bulk of language reflects adjective-noun pairs rated < 4 on typicality (i.e. ‘sometimes’, ‘rarely’ or ‘never’).

Talk about the Highly-Typical. Though there is striking consistency of description in caregiver speech across development, our mixed effects model revealed a negative effect of age. In line with our hypotheses, it seems that caregivers are more likely to provide description of typical features for their young children, compared with older children.

Indeed, when we look at the proportion of all description that is about highly-typical features (i.e. features that are ‘often’, ‘almost always’, or ‘always’ true), we see a significant

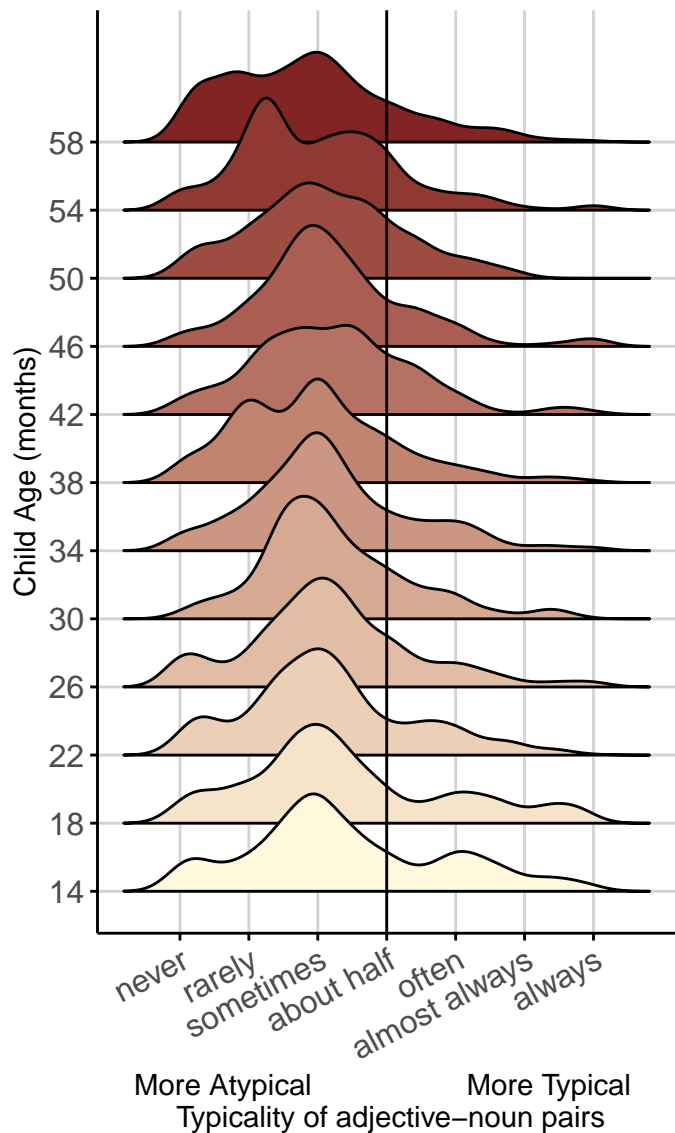


Figure 1: Density plots showing the usage amount at each timepoint based on the typicality of the adj-noun pair.

negative correlation with age ($r = -0.8231762$, $p < 0.01$). While children at all ages hear more talk about what is atypically true (see figure 1), younger children hear relatively more talk about what is typically true than older children do (figure 2).

Discussion

In sum, language is used to discuss atypical, rather than typical, features of the world. Description in caregiver speech seems to largely mirror the usage patterns that we observed in adult-adult speech, suggesting that these patterns arise from general communication pressures. Indeed, even children's own productions show a similar usage pattern, with more description of atypical features of the world as early as we can measure.

It should be noted that children's utterances come from nat-

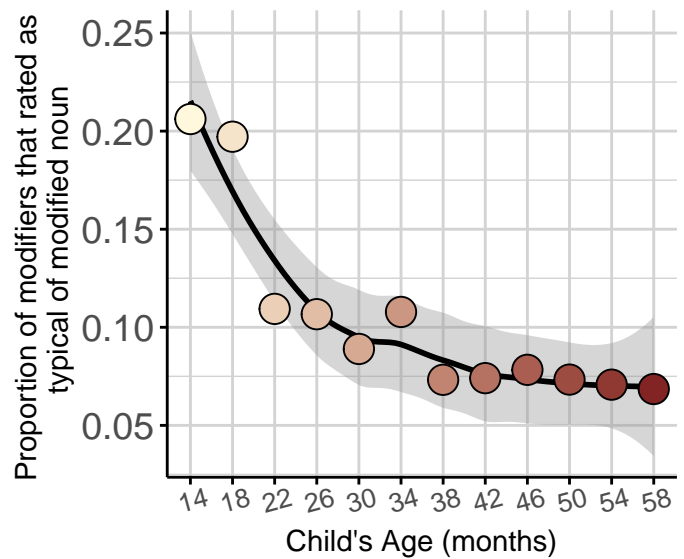


Figure 2: This plot shows the proportion of caregiver description that is about typically-true features, as a function of age.

uralistic conversations with caregivers, and their pattern of description is likely highly dependent on that caregiver's utterances. That is, if a parent chooses to describe the *purple-ness* of a cat in book, the child may well respond by asking about that same feature. Thus, it is possible that some of the children's use of atypical description is prompted by a parent-led discourse. Future analyses would need to better disentangle the extent to which children's productions are imitative of caregivers.

While children's own descriptions largely mirror adults', we do see some evidence that children's linguistic environment changes across development, becoming increasingly focused on atypical features. The higher prevalence of typical descriptors in early development may help young learners; however, even at the earliest point we measured, the vast majority of language input describes atypical features.

Across adult, parent, and child language corpora, we find robust evidence that language use systematically overrepresents atypical features. This usage aligns with the idea that language is used informatively in relation to background knowledge about the world. It may pose a problem, however, for young language learners with still-developing world knowledge. If language does not transparently convey the typical features of objects, and instead (perhaps misleadingly) notes the atypical ones, how might children come to learn what objects are typically like? One possibility is that information about typical features is captured in regularities across many utterances. If this is true, language may still be an important source of information about typicality as children may be able to extract more accurate typicality information by tracking second-order co-occurrence.

Other Ways of Extracting Structure from Language?

Second-order Co-occurrence

Much information can be gleaned from language that does not seem available at first glance. Kim et al. (2019) demonstrate blind people’s striking convergence with sighted people’s feature judgments about animals, and posit that blind people may use animal taxonomy knowledge to selectively generalize features between species. In a response, Lewis et al. (2019) note that complex inferential machinery is not necessary to make these nuanced generalizations, and in fact much of this feature information is captured by simpler associations between words in the language one hears. We take a similar approach to ask whether typical feature information is expressed in the structure of the language children hear.

Information in language goes beyond what can be learned from any one utterance. Though one might never hear the words /kumquat/ and /grapefruit/ in the same sentence, their common contexts—other words like /eat/, /rind/, /tree/, /tart/, and /seeds/—are clues that they have some similarities. Models of distributional semantics capitalize on these patterns by representing words using their contexts, and judging two words to be similar if they are surrounded by similar sets of words. Though we found that children get more information about atypical than typical features of objects on the utterance level, perhaps patterns of language use across many utterances could be used to extract typical feature information.

Word2Vec To test this possibility, we trained word2vec, a model that predicts words using their contexts, on the same corpus of child-directed speech used in our first set of analyses. Our model is a continuous-bag-of-words word2vec model trained using the package gensim [CITE]. If the model captures information about the typical features of objects, we should see that the model’s word pair similarities are correlated with the typicality ratings we elicited from human raters.

Results We find that similarities in the model have near zero correlation with human adjective–noun typicality ratings ($r = 0.018$). This is in spite of better correlations with large sets of human similarity judgments between different kinds of word pairs (correlation with wordsim353, 0.37; correlation with simlex, 0.15). This suggests that statistical patterns in child-directed speech are likely insufficient to encode information about the typical features of objects, despite encoding at least some information about word meaning more broadly. However, the corpus on which we trained this model was small; perhaps our model did not get enough language to draw out the patterns that would reflect the typical features of objects. To test this possibility, we asked whether word vectors trained on a much larger corpus—English Wikipedia—strongly correlate with typicality ratings. We find that while the correlation between similarities in the Wikipedia-trained model and human noun–adjective typicality ratings is stronger, it is still fairly weak at $r = 0.24$.

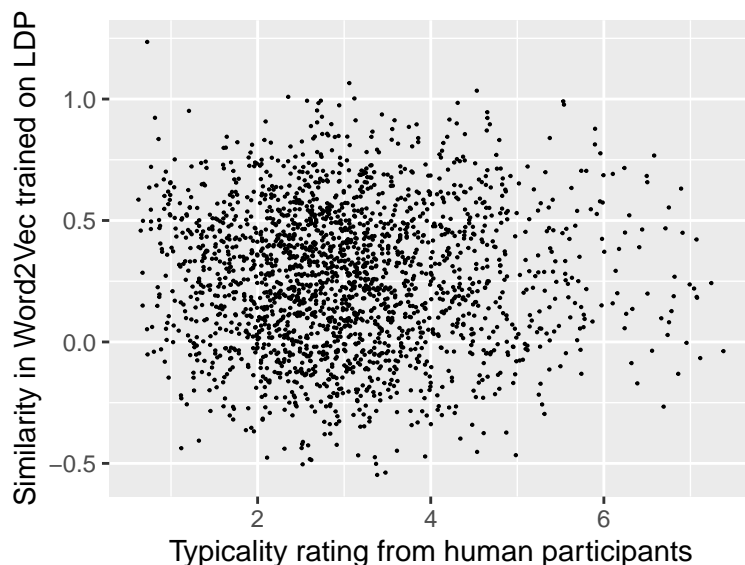


Figure 3: Correlation between vector similarities in word2vec (trained on the LDP corpus) and human-rated typicality judgments for our noun-adjective pairs.

Strikingly, the correlation between similarities in our model and similarities in the Wikipedia-trained models is stronger ($r = 0.33$) than either model’s correlations with human judgments. This suggests that these models are picking up on some systematic associations between nouns and adjectives, but not typical ones. Overall, these results suggest that models of distributional semantics fail to extract typical feature information from language in which atypical features are more often described.

Syntax

General Discussion

Language provides children a rich source of information about the world. However, this information is not always transparently available: language’s use to comment on the atypical and surprising means it does not perfectly mirror the world. Among adult conversational partners whose world knowledge is well-aligned, this characteristic of language allows people to converse informatively and not redundantly. But between a child and caregiver whose world knowledge is asymmetric, this pressure competes with other demands: what is minimally informative to an adult may be misleading to a child. The pressures that structure language may create a peculiar learning environment.

Here, we asked how children might use language to learn about the features of things. If caregivers use language to mirror the world or to teach their children about the typical features of things, they should often use highly typical adjectives to describe nouns. If, on the other hand, they speak informatively to convey what is atypical or surprising in relation to their own sophisticated world knowledge, they should more often mention the atypical features of things. We find

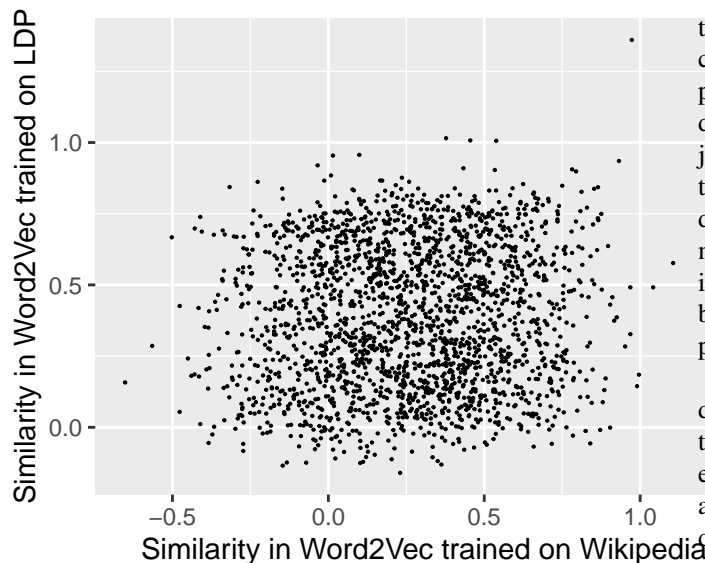


Figure 4: Correlation between vector similarities in word2vec trained on the LDP corpus and vector similarities in word2vec trained on English Wikipedia for our noun-adjective pairs.

that across a broad age range of 14 to 58 months, caregivers predominantly mention atypical features of objects. This pattern broadly mimics adults’ general language use tendencies. While caregivers do describe slightly more typical features to younger children, the overall trend of more often describing atypical features is strikingly consistent.

How, then, do children learn from language about the typical features of things? Patterns in language can convey more than the sum of individual utterances. We next considered whether co-occurrence statistics in language could be used to extract feature information that is not trivially available on the utterance level. We trained word2vec, a model that represents words by the contexts in which they occur, on our corpus of caregiver–child interactions. We find that similarity measures from this model have near-zero correlation with human typicality ratings of adjective–noun pairs. Further, a state-of-the-art model trained on a much larger corpus has a low correlation with these human judgments. Interestingly, similarity measures from our model and from the highly-trained model had a higher correlation than either model did with human judgments. It seems that these models are picking up similar regularities in use of nouns and adjectives, but that these regularities do not reflect the typical features of things.

One source of information that may simplify this problem is perceptual information from the world itself. It is possible that children see enough orange carrots in the world to swamp any potential confusion brought on by hearing “purple carrot.” Putting aside such abundantly available categories, it is still unclear how children learn about categories of objects they have less access to, or those that cannot be learned about by direct experience. Abstract concepts are a crucial example. Children have scant information in the world other

than language to learn about abstract concepts. These concepts may be described differently than concrete objects—parents may reasonably provide more typical adjectives to describe them—but if they pattern similarly to concrete objects, children are in a particularly difficult bind. And, further, perceptual availability does not explain how blind children and adults extract largely veridical visual featural information. While perceptual information is undoubtedly useful in learning about the typical features of things, it remains to be explained how feature information is extracted when this perceptual information is scant, irrelevant, or incomplete.

Another potential simplification to this problem is that children know something about how to use language informatively at a young age. Under this hypothesis, their language environment is not misleading at all: if young children expect adjectives to be used to mark atypical features, they can use description and the lack thereof to learn more about the world around them. Lab studies find that children expect interlocutors to be informative in relation to their prior knowledge by the age of 2 (Akhtar et al., 1996) and that 5–6-year-old children are roughly informative with respect to their interlocutor’s perspective in a referential communication task (Nadig & Sedivy, 2002). More naturalistic studies find that children at the one-word stage selectively imitate words that convey new information—that is, words that are informative with respect to what is obvious or assumed in the environment—when describing events (Greenfield & Zukow, XXXX). The idea that young children understand the informative purpose of language is consistent with our finding that children also largely choose to describe atypical features. Though this effect can be explained by simpler means such as salience or mimicry, it suggests that caregivers and children may be usefully aligned in the aspects of the world they choose to talk about.

Overall, we find that caregiver and child uses of description show remarkable consistency with use of description in adult–adult speech: people talk about the atypical. Though it is intuitive that parents might be broadly over-informative in order to teach their children about the world, this is not the case: they seem to instead speak informatively in relation to knowledge about the world. This presents a potential puzzle for young learners who have limited world knowledge and limited pragmatic inferential abilities. Perceptual information and nascent pragmatic abilities may help fill in the gaps, but much remains to be explored to link these explanations to actual learning. Communication pressures are pervasive forces structuring the language children hear, and it remains to be seen whether children capitalize on them or are misled by them in learning about the world.

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