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Distributional structure in language: Contributions to noun–verb difficulty differences in infant word recognition

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ABSTRACT

What makes some words easy for infants to recognize, and other words difficult? We addressed this issue in the context of prior results suggesting that infants have difficulty recognizing verbs relative to nouns. In this work, we highlight the role played by the distributional contexts in which nouns and verbs occur. Distributional statistics predict that English nouns should generally be easier to recognize than verbs in fluent speech. However, there are situations in which distributional statistics provide similar support for verbs. The statistics for verbs that occur with the English morpheme –*ing*, for example, should facilitate verb recognition. In two experiments with 7.5- and 9.5-month-old infants, we tested the importance of distributional statistics for word recognition by varying the frequency of the contextual frames in which verbs occur. The results support the conclusion that distributional statistics are utilized by infant language learners and contribute to noun–verb differences in word recognition.

1. Introduction

How do infants come to recognize words in fluent speech, and why do they find some words easier to recognize than others? This question is a complex one, and is difficult to answer. But the answer is important, because word recognition is a critically important process with consequences for many downstream language processes. If infants do not recognize a familiar word in fluent speech, their ability to match its sounds to its referent will be impaired (Graf Estes, Evans, Alibali, & Saffran, 2007; Hay, Pelucchi, Graf Estes, & Saffran, 2011). Familiar words that go unrecognized will not be available as a cue to the boundaries of novel words in fluent speech (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005; Mersad & Nazzi, 2012). Further, an infant who is not recognizing words in fluent speech is missing out on a wealth of distributional information about the word's co-occurrences with other words (Fernald, Perfors, & Marchman, 2006; Swingley, Pinto, & Fernald, 1999). Infants' ability to quickly and efficiently recognize words in context is a strong predictor of vocabulary growth and other aspects of language processing (Fernald & Marchman, 2012; Marchman, Fernald, & Hurtado, 2010). These facts demonstrate the importance of a thorough understanding of why infants can recognize some words easily, but have difficulty with others.

The goal of the current research was to further investigate this process by examining the role that words' distributional contexts might play in facilitating infant word recognition. As a means to that end, we studied a specific case in which infants have word recognition challenges: recognizing verbs (relative to nouns). A large body of research, involving many languages and methodologies, indicates that children learn about nouns more easily than verbs (see Golinkoff & Hirsh-Pasek, 2006, for a review). It has been suggested that this noun advantage may begin

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at the earliest stages of language acquisition, with infant word recognition. For example, whereas native-language nouns can be reliably recognized in continuous speech by 6.0–7.5 month olds (Bortfeld et al., 2005; Jusczyk & Aslin, 1995), similar performance with verbs does not appear to emerge until 11.0–13.5 months of age (Nazzi, Dilley, Jusczyk, Shattuck-Hufnagel, & Jusczyk, 2005; Shi & Lepage, 2008).

A number of factors are known to be important contributors to word recognition difficulty. One of the most critical factors is a word's acoustical properties and sound structure. For example, infants have a much easier time recognizing words that follow their native language's phonotactic regularities, such as being consonant-initial in English (Jusczyk & Aslin, 1995; Nazzi et al., 2005). Infants also have an easier time recognizing sound sequences that follow their native language's typical stress pattern (Echols, Crowhurst, & Childers, 1997; Houston, Santelmann, & Jusczyk, 2004; Jusczyk, Houston, & Newsome, 1999; Morgan & Saffran, 1995; Nazzi et al., 2005).

However, there is also variation that cannot be explained by phonotactic and prosodic structure. For example, Nazzi et al. (2005) carefully manipulated verbs' phonotactics and prosody, and found big effects: infants recognized the "easy" verbs (consonant-initial verbs with strong–weak stress) at 13.5 months and did not recognize "hard" verbs (vowel-initial verbs with weak-strong stress) until 16.0 months. But 10.5-month-old infants failed to recognize even the "easy" verbs, a marked contrast with studies showing that infants as young as 6.0–7.5-month-olds recognize nouns in fluent speech (Bortfeld et al., 2005; Jusczyk & Aslin, 1995). Thus despite a considerable amount of focus on infants' word recognition abilities, and the identification of phonotactic and prosodic factors that contribute to noun–verb differences, a thorough understanding of this difference eludes us.

An additional factor, and one that might help explain the noun–verb gap, is the infant's familiarity with the immediate contexts in which nouns and verbs occur. Natural language statistics predict what words will be easy for adults to recognize (Duffy, Morris, & Rayner, 1988), comprehend (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Gennari & MacDonald, 2009; Trueswell, Tanenhaus, & Kello, 1993), and produce (Haskell, Thornton, & MacDonald, 2010). And it is known that very young language learners engage in statistical learning, which occurs over various elements in the linguistic input as well as the environments in which utterances occur (Saffran, Aslin, & Newport, 1996; Smith, Yu, & Pereira, 2011). It has also been established that nouns and verbs differ systematically with respect to language statistics that affect language processing. In general, these differences favor nouns over verbs (Hills, 2013; St. Clair, Monaghan, & Christiansen, 2010; Willits, Seidenberg, & Saffran, 2009), consistent with the overall noun advantage observed in behavioral studies. We present new behavioral and quantitative evidence supporting this explanation, complementing previous findings.

However, the distributional context explanation makes a further prediction. If these distributional statistics are an important factor in word recognition, then in situations where verbs *are* more similar to nouns with respect to relevant distributional statistics, they should be as easy to recognize as nouns. English affords a way to test this hypothesis. In English, distributional statistics generally favor nouns over verbs, with more frequently and consistently occurring distributional frames. For example, nouns most frequent distributional collocation (*the*) has a considerably higher co-occurrence probability with nouns ($p = 0.192$) than verbs most frequent collocation (*you*, $p = 0.117$).[1] Nouns on average also co-occur with a smaller subset of words than verbs – giving them more consistent contextual collocation cues [$\overline{X} = 3.55\%$ (SE = 0.23%) for nouns, compared to $\overline{X} = 4.50\%$ (SE = 0.40%) for verbs, $t(299) = 2.047$, $p < 0.05$]. It has been shown that the frequency and consistency of distributional frames contributes to infants' ability to recognize adjacent words (Bortfeld et al., 2005; Mintz, 2013; Shi, Cutler, Werker, & Cruickshank, 2006; Shi & Lepage, 2008) and is correlated with words' age of acquisition (Hills, 2013).

English also provides situations where verbs' distributional statistics become more like nouns. One such example is verbs that occur in –*ing* contexts. This situation renders a distributional context that is noun-like in its potency. If –*ing* were treated as a separate unit in language, this would make it the sixth most frequent word in the English language.[2] As a frequent anchor collocation of verbs, its co-occurrence probability with verbs is $p = 0.162$, considerably higher than the next most frequent word (*you*, $p = 0.117$) and more in line with nouns' most frequent co-occurring element (*the*, $p = 0.190$). Thus, verbs occurring in –*ing* contexts provide an ideal circumstance for testing whether distributional factors like anchor word co-occurrence are important for infant word recognition.

There are a number of other reasons to think that young infants should have an easier time recognizing verbs in –*ing* contexts, and that this difference may be enough to make the noun–verb gap disappear. Behavioral evidence suggests that older infants use highly frequent morphological units such as –*ing* as a segmentation or recognition cue. Mintz (2013) found that much older infants (18-months) are facilitated in segmenting novel sound sequences from fluent speech when they are heard in an –*ing* context (but not an unfamiliar –*dut* context). Similarly, Marquis and Shi (2008) found that French-learning 11-month-olds show facilitated recognition of French verbs in the highly frequent –*er* inflectional form (see also Marquis & Shi, 2012).

We therefore hypothesized that infants may show enhanced verb recognition, when the target verbs appear in the highly felicitous –*ing* context. If so, this would lead to three major conclusions. First, an important contribution to differences between nouns and verbs in recognition difficulty would be attributable to distributional differences of the contexts in which those words occur. Words with more useful distributional statistics would be recognizable at earlier ages. Second, although nouns *tend* to have distributional statistics that are more useful for word

[1] Statistics were calculated using the 150 most frequent nouns and 150 most frequent verbs in the CHILDES corpus (MacWhinney, 2000).

[2] As with the previous analyses, this numbers were computed using all samples of child-available speech in the CHILDES database.

recognition, verbs are not necessarily or intrinsically more difficult to recognize than nouns, because they can be recognized just as easily as nouns in favorable statistical contexts (specifically, English sentences where *–ing* acts as a strong distributional cue). Third, the predicted result would provide evidence that highly frequent subword units such as *–ing* are picked up rapidly by language learners and enter into the computation of sequential statistics that are relevant to early word recognition.

In the following experiments, we tested the hypothesis that English distributional statistics contribute to the observed noun–verb age gap in word recognition. Experiment 1 examined whether 9.5-month-olds recognize high frequency, familiar verbs in their most frequent lexical distributional frames. Critically, these lexical distributional frames were not as frequent or consistent as the most frequent distributional frames for nouns. In Experiment 2, we tested the same verbs in *–ing* frames with 9.5- and 7.5-month-old infants. This study allowed us to test the hypothesis that infants can use the highly frequent *–ing* frame to recognize verbs, and to determine whether equating noun–verb distributional statistics eliminates the noun advantage all the way down to 7.5 months of age.

2. Experiment 1

As discussed earlier, previous research found that while 6.0–7.5-month-old infants recognize nouns from fluent speech (Jusczyk & Aslin, 1995), infants do not show evidence of recognizing verbs until 11.0–13.5 months (Marquis & Shi, 2008; Nazzi et al., 2005). It is possible that the observed differences in noun and verb recognition were contributed to by differences in the languages that were tested; (Marquis & Shi, 2008 was in French), while the noun studies (Bortfeld et al., 2005; Jusczyk & Aslin, 1995) were in English. It is also possible that these differences were influenced by a simple factor such as the relative frequency of the nouns and verbs used across the studies (the nouns used by Jusczyk and Aslin were quite high in frequency compared to the verbs used by Nazzi et al.). It is also possible that this age difference was due to differences in the frequency of the target words' lexical frames. The nouns' frames in the previously cited study were extremely high frequency (e.g. "*the* <u>*dog*</u> *is*...."), whereas the verbs' frames in Nazzi et al. were much lower frequency ("...*comet* <u>*orbits*</u> *Earth*..."). Nevertheless, it is possible that infants presented with high frequency verbs in their highest frequency lexical contexts may still perform more poorly on verbs than nouns, because verbs' best lexical contexts are not as frequent as nouns' best lexical contexts. Thus, Experiment 1 serves as a replication of Nazzi et al. (2005) and Marquis and Shi (2008) with English materials and learners, to ensure that their null findings with younger infants are not due to French-specific factors or due to differences in the frequencies of the target verbs.

In Experiment 1, we tested whether the use of frequent verb targets and frames provides sufficient support for infants to recognize English verbs. We tested 9.5-month-old infants, an age intermediate between the age at which infants recognize nouns (7.5 months) and the youngest age at which infants have been shown to recognize verbs (11.0 months), as a first attempt to determine whether improving verbs' distributional statistics would lead to verb recognition at younger ages than shown in previous studies.

2.1. Method

2.1.1. Participants

Twenty-four 9.5-month-old monolingual infants from English-speaking families participated in the study (mean age 9.4 months; range: 37–42 weeks). All of the participants were typically developing and full-term according to parental report. Eight additional infants were tested but not included in the analyses due to crying during more than half the test trials.

2.1.2. Stimuli

The target verbs were *kiss*, *drink*, *give*, and *walk*. These verbs were chosen to be similar in familiarity and frequency to the nouns used in Jusczyk and Aslin's (1995) study, based on parental report (receptive MCDI; Dale & Fenson, 1996) and frequencies in child-directed speech (computed from all corpora in the CHILDES database directed at infants 12 months and younger; MacWhinney, 2000). The familiarization materials consisted of two counterbalanced stimulus corpora (the first had 12 sentences, six containing *kiss* and six containing *give*, the second also had 12 sentences, six containing *drink* and six containing *walk*). In order to construct the familiarization sentences, we used the CHILDES database to find the six most frequent frames for each verb, using the method similar to Mintz (2003). This consisted of taking each verb and using the corpus to select the six most frequent trigrams containing that verb (e.g. "...*to* <u>*kiss*</u> *me*..." "...*I'll* <u>*kiss*</u> *you*..."). These frames were used to generate six semantically plausible sentences for each verb. Each verb occurred once as the first word, once as the last word, and four times at varying points in the middle of a sentence. In each set of six sentences, the other content words occurred only once. Each verb's set of six sentences had equivalent word and syllable lengths. See Appendix A for a list of the familiarization sentences. The test stimuli consisted of all four verbs (*kiss*, *drink*, *give*, and *walk*). As such, which verbs were the "familiarized" verbs and which were the "unfamiliarized" verbs varied as a function which training corpus the infant heard.

The materials were all recorded in a soundproof booth using professional recording equipment. The stimuli were spoken by an adult female speaker in a child-directed manner, and edited to equalize amplitude.

2.1.3. Procedure

Infants were tested individually in a 2-x-2-meter sound-attenuated booth while seated in their caregiver's lap. The caregiver listened to masking music over closed-ear headphones. The experiment was run using the Headturn Preference Procedure (Kemler-Nelson, Jusczyk, Mandel, & Myers, 1995), and consisted of a familiarization phase and a test phase. During the familiarization phase, each infant heard a familiarization corpus consisting of 12 sentences, six using one verb, and six using the other verb. The sentences were presented in blocks, such that all six sentences for a particular verb were played in a row, with a one second pause between each sentence. The alternating blocks of six sentences were repeated four times. The total familiarization time was approximately 140 s.

While the infants listened to the familiarization corpus, they were also exposed to flashing lights that they could control via their looking behavior. During the familiarization phase the lights were not contingent on the sounds being played. At the beginning of the familiarization phase, a center light in front of the infant flashed, and when the infant looked at it, a light on either the left wall or the right wall (chosen randomly) began to flash. Once the infant looked at the side light, it continued to flash until the infant looked away for more than two seconds, upon which the center light would begin to flash and the sequence of events would repeat.

After the familiarization period, the test phase began. During the test phase the presentation of sounds *was* contingent on the infant's looking behavior. At the beginning of each of the 12 test trials, the center light started flashing, and when the infant looked at it, a side light would begin to flash. When the infant looked at the side light, one of four verbs (either one of the two verbs the infant heard during familiarization, or one of the two unfamiliarized verbs) began playing from a speaker mounted next to the flashing light. The verb repeated with a 600 ms interval between each repetition until the infant looked away from the flashing light for more than 2 s, or until a maximum trial length (15 repetitions) was reached.

2.2. Results and discussion

A 2-x-2 mixed ANOVA was conducted on looking times to the four test verbs, testing for effects and interactions of counterbalancing condition (familiarization corpus A vs. familiarization corpus B) and whether or not the verb was familiarized or unfamiliarized. Neither the counterbalancing factor nor the interaction between counterbalancing and familiarization were significant (both F's < 1). The main effect of familiarization was also not significant, $F(1,23) = 1.85$ $p = 0.186$: infants did not reliably discriminate familiarized verbs from unfamiliarized verbs. The looking times for Experiment 1 are shown in Fig. 1.

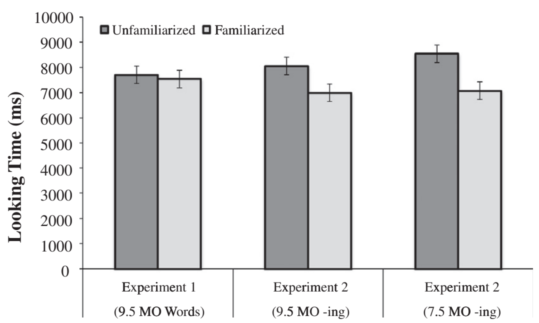

Fig. 1. Infants looking time (ms) to Familiarized and Unfamiliarized Verbs in all four experiments.

The failure of 9.5-month-old infants to discriminate trained verbs from untrained verbs is consistent with previous studies (Marquis & Shi, 2008; Nazzi et al., 2005). Their difficulty in verb recognition persisted despite stacking the deck in their favor, by making the verbs and their contexts extremely high in frequency and "simple" in terms of factors known to aid word recognition. The verbs were among the most frequent in child-directed speech, were stressed, were consonant-initial, and were presented in the verbs' most frequent lexical frames. Despite making the task of recognizing verbs as easy as possible in terms of all these characteristics, 9.5-month-old infants still did not show evidence of recognizing verbs to which they had been exposed in fluent speech, an age at which infants are already showing clear evidence of recognizing nouns.

3. Experiment 2

As noted above, one possible explanation for infants' failure to recognize the verbs in Experiment 1 is that distributional differences between nouns and verbs may typically privilege noun recognition over verb recognition. Verbs' most frequent lexical frames are less frequent and co-occur with verbs less often than nouns' most frequent lexical frames. One way to test this hypothesis is by examining circumstances where the statistics privilege verbs as much as nouns. One such situation in English is for verbs in *–ing* frames. On this view, the presence of *–ing* in verb frames should facilitate the recognition of the verb roots. We tested this hypothesis in Experiment 2.

3.1. Method

3.1.1. Participants

Forty-eight infants from monolingual English-speaking families participated in Experiment 2. Half of the infants were between the ages of 9 and 10 months (mean age 9.3 months; range: 37–42 weeks), and the other half were between the ages of 7 and 8 months (mean age 7.6 months; range: 30–35 weeks). Thirteen additional infants were tested but not included due to crying during more than half the test trials. None of the infants had participated in Experiment 1.

3.1.2. Stimuli and procedure

The procedure was identical to Experiment 1. The same target verbs from Experiment 1 were used in Experiment 2. As in Experiment 1, during the familiarization phase infants heard 12 sentences containing two verbs (again divided into one of two counterbalanced familiarization corpora). Unlike Experiment 1, the verbs occurred in a frame that included the *–ing* inflection. The exact frames were once again chosen using the CHILDES corpus to identify the six most frequent frames (trigrams) for the verbs when they were used in their *–ing* form. Six sentences were constructed for each verb using these frames (see Appendix A). The amplitude of the passages was the same as those in Experiment 1. In addition, we ensured that the sentences in both passages were, on average, equal in length in Experiment 1 vs. Experiment 2 [5.33 vs. 5.17,

$t(46) = 0.59$, $p = 0.56$)], and that the position of the target word in the sentence was on average the same across the two experiments [3.54 vs. 3.50, $t(46) = 0.94$, $p > 0.05$]. The test items were identical to Experiment 1, and critically, were still presented in root form, without –*ing*.

3.2. Results and discussion

The looking times for Experiment 2 are shown in Fig. 1. A 2-x-2-x-2 mixed ANOVA was conducted on listening times to the four test verbs, testing for effects of (1) age, (2) counterbalancing condition (familiarization corpus A vs. familiarization corpus B), and (3) whether the verb was familiarized or unfamiliarized. Age and counterbalancing were not significant factors, nor did they interact with any other factors (all F's < 1). However, the main effect of familiarization was significant: infants looked significantly longer on trials consisting of unfamiliarized verbs, $F(1,47) = 8.52$, $p < 0.01$). Separate analyses looking at this factor separately for infants in both age groups were also significant both for 9.5-month-olds: $F(1,23) = 8.05$, $p < 0.01$) and for 7.5-month-olds: $F(1,23) = 8.91$, $p < 0.01$).

To test the hypothesis that the –*ing* frame facilitated word recognition, we conducted an additional 2×2 ANOVA combining the results from Experiments 1 and 2 (using the more comparable 9.5-month-old infants from Experiment 2).[3] This analysis included familiarization (familiarized verb vs. unfamiliarized verb) and verb inflection type (the uninflected verbs from Experiment 1 vs. the –*ing* inflected verbs from Experiment 2). There were no main effects of familiarization condition or verb inflection type (both F's < 1), but there was a significant interaction, $F(1,23) = 2.15$, $p < 0.05$. Follow-up tests using pooled standard error from both experiments (Keppel & Wickens, 2004) revealed that there was a significant difference in looking times to familiarized versus unfamiliarized verbs for infants in the *ing*-inflected condition (Experiment 2), $F(1,23) = 10.05$, $p < 0.001$, but not for infants in the root verb condition (Experiment 1), $F(1,23) = 1.63$, $p = 0.214$.

The direction of this effect (a novelty effect, suggesting preferential listening to the new items) is atypical compared to other experiments that have tested infant word recognition. The Jusczyk and Aslin (1995) and Bortfeld et al. (2005) studies with frequent nouns, as well as Shi and colleagues' studies with verbs, have all found familiarity effects (preferential listening for the previously trained items). The mechanisms and underpinnings of when an infant will show a familiarity effect vs. a novelty effect are not completely understood, but one hypothesis is that the difference arises as a function of difficulty (Houston-Price & Nakai, 2004; Hunter & Ames, 1988; Thiessen & Saffran, 2003). According to this explanation, infants who are having an easy time processing a particular stimulus should habituate to that stimulus more quickly, and thus more quickly switch to attending to a novel stimulus. In contrast, infants who are having more difficulty processing a stimulus may still be in a phase of actively learning about that stimulus during the test phase, and thus more likely to show a preference for the items on which they had just been trained. Returning to our findings, our demonstration of a novelty preference could thus be taken as evidence not just that infants *can* discriminate verbs in fluent speech with an –*ing* context, and that they find this to be relatively easy.

Together the results of the two experiments support the hypothesis that bound morphemes can facilitate word recognition in fluent speech (see also Mintz, 2013; Shi & Marquis, 2009). Fig. 2 shows the average bigram probabilities of the nouns in Jusczyk and Aslin's (1995) study, in which 7.5-month-old infants recognized nouns, as well as the bigram probabilities for the verbs in Experiment 1 and 2, counting –*ing* as a separate unit for these calculations. Replicating the language-general trends, the root verb bigram probabilities in Experiment 1 are reliably lower than both the nouns from Jusczyk and Aslin's study, $F(1,46) = 4.95$, $p < 0.05$, and the –*ing* frame verbs in Experiment 2, $F(1,46) = 11.41$, $p < 0.001$. However, the verbs used in –*ing* frames in Experiment 2 were not significantly different from Jusczyk and Aslin's nouns, $F(1,23) < 1$, $p > 0.05$). The behavioral results follow the predictions derived from these distributional facts.

The results of Experiment 2 demonstrates that in the presence of –*ing* frames, 7.5 and 9.5-month-old infants can successfully recognize verbs in fluent speech. While there *is* a noun–verb gap in terms of the difficulty of word recognition, this gap is understandable at least in part in terms of nouns' typically more statistically useful distributions. Nouns typically have high frequency collocations (like *the*) which bootstrap recognition, in line with mechanisms suggested by Bortfeld et al. (2005) and Shi et al. (2006). In line with this hypothesis, in circumstances where these distributions are equated (such as –*ing* frames), verb recognition is comparable to noun recognition.

4. General discussion

Why are some words easy for infants to recognize in fluent speech, and other words difficult? An important part of the answer to this question has to do with infants' abilities to recognize and track distributional statistics about words. These includes item-level regularities such

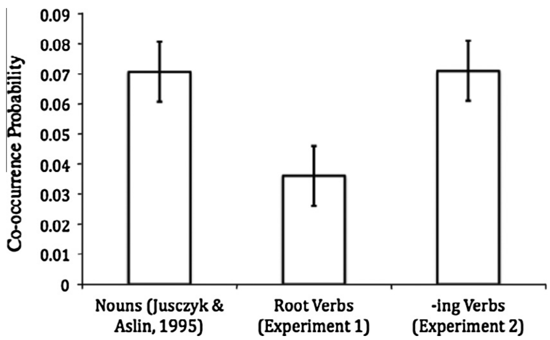

Fig. 2. Average bigram probabilities for the target words and their preceding and following contexts for the nouns in Jusczyk and Aslin's (1995) study and the verbs from our experiments.

[3] The results of this analysis do not change if the 7.5-month-olds infants are used in place of the 9.5-month-olds.

as phoneme, syllable, and morpheme transition probabilities, as well as more abstract, language-wide general properties such as a language's modal stress and phonotactic regularities. Although it has been established that infants are sensitive to a broad range of statistical relationships very early in life, many questions remain concerning which of these factors matter for infants' ability to recognize words in fluent speech.

One approach to answering this question involves identifying statistical regularities via quantitative analyses of large corpora, such as caregiver speech to children (Goldwater, Griffiths, & Johnson, 2009; Mintz, 2003; Redington, Chater, & Finch, 1999; St. Clair et al., 2010), adult speech (Gennari & MacDonald, 2009; Hare, McRae, & Elman, 2004) or written texts (Burgess & Lund, 1997; Jones & Mewhort, 2007; Landauer & Dumais, 1997). Corpus analyses have identified several types of statistical regularities that could be beneficial to language users. Behavioral experiments can then determine whether these statistics are used in online processing. The present research took this approach, addressing the role of statistical structure in language processing by examining the frequency and co-occurrence probability of words' most frequent frames or contexts in a natural language (English). We examined whether those statistics were predictive of some aspects of early word recognition, and in particular whether some of the noun advantage in early language acquisition has its origins in the distributional statistics that infants are learning in the first year of life.

Are nouns easier for infants to recognize than verbs, as suggested by previous research? Experiment 1 demonstrated that 9.5-month-old infants failed to show evidence of discriminating between verbs they had just heard and verbs they had not. This occurred under seemingly advantageous conditions: the verbs were very high frequency, consonant-initial, and were presented in their most frequent lexical frames. In contrast, younger infants recognize nouns under similar circumstances (Bortfeld et al., 2005; Jusczyk & Aslin, 1995). Thus, even when target frequency and phonotactics are controlled, there is a noun advantage. The question is, why?

A number of factors influence the difficulty of processing speech, including word frequency (Shi et al., 2006), lexical stress (Echols et al., 1997; Johnson & Jusczyk, 2001; Jusczyk et al., 1999; Morgan & Saffran, 1995; Nazzi et al., 2005) and phonotactic regularity (Mattys & Jusczyk, 2001; Nazzi et al., 2005). Many of these factors are correlated with grammatical class in many languages, and conspire to make nouns easier to recognize than verbs. But our findings in Experiment 1, which stacked the deck for verbs in favor of all of these factors, still failed to find evidence of 9.5-month-olds recognizing some of the highest frequency verbs in the English language.

The results of Experiment 2 provide evidence that, in addition to prosodic/phonotactic factors, distributional statistics – such as the frequency of a word's co-occurring frame – also have a large impact on infant word recognition. Simple distributional statistics suggest that in English, nouns have more frequent anchor words and tend to have more frequent and more consistent distributional contexts. The advantage for nouns could be due in part to statistical properties of English. However, the statistics vary, and there are some cases in which verb statistics are comparable to nouns. The present studies examined one prominent case of this sort: verbs that end in –*ing*. If –*ing* is treated as a unit over which statistics are computed, its statistical relation to verbs is like that of *the* to nouns. Experiment 2 demonstrated that infants are sensitive to the useful context that –*ing* provides; the same root verbs that could not be recognized in Experiment 1 were recognized by 7.5-month-old and 9.5-month-olds (Experiment 2) when they occurred in –*ing* frames.

This evidence concerning the distributional relationship between a word and its most frequent contexts suggests a new approach to explaining the noun–verb gap in infant word recognition. This approach is doubly informative because it provides an explanation for the general tendency of nouns to be easier than verbs at these young ages, and also an explanation for the exceptions (such as –*ing* inflected verbs) to this rule. In our view, this explanation converges with research by Monaghan, Christiansen, and Chater (2005) "Phonological-Distributional Coherence Hypothesis" (see also Monaghan, Chater, & Christiansen, 2005; Onnis & Christiansen, 2008). Monaghan and colleagues note that both distributional and phonological sources of information (a superset of features that includes both stress and phonotactic regularities) combine to create an extremely useful set of joint cues. Critically, Monaghan and colleagues note that distributional information tends to be more useful for classifying and learning about nouns, while phonological information is more useful for learning about verbs, a claim that our findings help support.

Our results have important implications about the overall developmental trajectory of child word learning, especially with regard to noun–verb differences. The ability to recognize a word in fluent speech is established to be a strong predictor of their ability to map that word to a referent in the world (Graf Estes et al., 2007; Hay et al., 2011), and to learn about semantic relationships between a word and its thematic relations (Fernald et al., 2006; Swingley et al., 1999). A large number of recent studies have begun documenting impact of word processing on downstream language learning outcomes. A number of studies have found that infants' speed of word recognition is predictive of language and cognitive outcomes later in life (Borovsky, Elman, & Fernald, 2012; Fernald & Marchman, 2012; Marchman & Fernald, 2008; Marchman et al., 2010). If infants do not recognize a word, they cannot take note of its possible visual referents, its thematic relations, or its other associated contexts in language and in the world.

Thus, the fact that nouns tend to be more easily recognized may indeed point to this as an important reason that children get a head start learning about nouns. However, the fact that there are conditions under which verbs are easier to recognize (such as in –*ing* frames) means that verbs that tend to be used in these frames may be more quickly learned about, or that episodes in which verbs occur in –*ing* frames may more useful for learning about the verb's meaning and semantic relationships, or may contribute more to early lexical representations. These are consequential predictions of our distribution-based learning explanation that could be tested in future research.

The results also have implications concerning our understanding of the word recognition process. First, the results underscore the importance of highly frequent morphological forms acting as anchor or contextual cues. These findings are concordant with others in the infant word recognition literature (Bortfeld et al., 2005; Shi & Marquis, 2009), as well as considerable work with adults demonstrating facilitated word recognition in the presence of high frequency and highly consistent contexts (Duffy et al., 1988).

As stated at the outset, the goal of our research was to examine why some words are easy for infants to recognize and other are difficult – and specifically, the role of distributional statistics in explaining these differences. Our results suggest that noun–verb differences in acquisition arise in part from properties of the language to which the infant is exposed. The underlying generalizations concern the relative informativeness of the contexts in which nouns and verbs occur. Given the structure of the input, and a learner who is developing representations of salient units and their distributional properties, an overall noun advantage emerges. These effects interact with a variety of other noun–verb differences (such as differences in prosodic and phonotactic structure) that also contribute to this developmental pattern.

This account is incomplete in many respects, and further research on English and other languages is needed. Clearly, language learners are tracking various kinds of information and developing representations of the language gradually under noisy, variable conditions, with different types of knowledge bootstrapping each other. Understanding a learning process of this complexity would benefit from having a computational model or some other type of formal analysis that can track such developments. Future research will include exploring different mechanistic accounts of how learning occurs under realistic conditions. A mechanistic account would help us to make predictions about how much the child needs to have learned about one unit of speech in order for it to bootstrap recognition of and learning about other units.

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Appendix A

Training Materials from Experiment 1

Training Corpus 1	Training Corpus 2
Walk a doggie in our park.	What does daddy want to drink?
Wanna walk over to your chair?	Is she gonna drink it?
She can't walk away from me.	Will he want to drink out of that?
Is daddy going to walk off the step?	Drink some water cause its good for you
Now we'll walk down these stairs.	Don't drink so much
Do you really want to walk?	Mommy can drink your milk now
Which teddy bear did she want to kiss?	Is he gonna give mommy a snack
Why does daddy want to kiss me?	Want to give it with the puppy?
Kiss him goodbye and be nice.	I'll give her my horsie.
I'll kiss you on your cheek.	What toy did you give?
Will he let mommy kiss his foot?	Give me that cookie and make him happy
Look at that boy kiss the baby.	Don't give food for daddy.

Training Materials from Experiment 2

Training Corpus 1	Training Corpus 2
He's walking over by your chair.	Drinking some water was good for you.
They're walking on the tall steps.	Where does daddy want to be drinking?
You're still walking when you're sleepy.	Mommy's just drinking that milk now.
Why are you and her just walking?	Finally they are drinking it.
Is she tired of walking yet?	What cup is he drinking out of?
Walking away from me isn't good.	She's not drinking much.
Kissing him goodbye will be nice.	Is he gonna be giving mommy food?
Mommy's kissing you on your cheek.	Giving me that cookie will make him happy.
Where am I kissing his foot?	What toy were you giving?
Why is daddy kissing me?	She's giving a snack to daddy.
Look at that boy kissing the baby.	We're not giving it with the puppy?
Which teddy bear was she kissing?	They are giving her my horsie.

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