
Learning New Words II: Phonotactic Probability in Verb Learning

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Phonotactic probability, a measure of the likelihood of occurrence of a sound sequence, appears to facilitate noun learning (H. L. Storkel, 2001). Nouns and verbs, however, tend to differ in rate of acquisition, indicating that word-learning mechanisms may differ across grammatical class. The purpose of the current study was to examine the effect of phonotactic probability on verb learning. Thirty-four typically developing preschool children participated in a multitrial word-learning task involving nonwords varying in phonotactic probability paired with unfamiliar actions. Multiple measures of word learning were obtained at increasing numbers of exposures. Correct responses were analyzed to examine rate of word learning. Results paralleled those of the previous noun-learning study, with common sound sequences being learned more rapidly than rare sound sequences. The results are interpreted in relation to the effect of distributional regularities on acquisition and the reported discrepancy between noun and verb learning in English.

KEY WORDS: normal language development, phonology, vocabulary expansion, preschool children, phonotactic probability

Children's ability to rapidly acquire new words is well documented (Bloom, 1973; Clark, 1973; Dickinson, 1984; Dollaghan, 1985; Heibeck & Markman, 1987; Nelson, 1973a; Rice & Woodsmall, 1988). One account of this rapid acquisition suggests that children learn the distributional regularities of the ambient language and that this knowledge, in turn, has consequences for word learning (Hollich et al., 2000; Plunkett, 1994; Smith, 1995, 1999). The influence of semantic (Grimshaw, 1981; Jones, Smith, & Landau, 1991; Pinker, 1984; Samuelson & Smith, 1999; Smith, 1995, 1999; Smith, Jones, & Landau, 1996), syntactic (Gleitman, 1990; Gleitman & Gleitman, 1992; Landau & Gleitman, 1985), and phonological regularities (Cassidy & Kelly, 1991; Cutler & Carter, 1987; Morgan, 1986) on word learning have been attested. One phonological regularity that children appear to learn early in development is *phonotactic probability*, which refers to the observation that certain phonotactically legal sound sequences are more likely to occur than others. Thus, certain sound sequences are common in a language, such as /koo/ in English, whereas other sound sequences are rare, such as /wat/ in English. The sound sequence in /koo/ is considered to be common because the individual sounds occur in the same word position in many other words of the language, and the adjacent sounds co-occur in many other words of the language. In contrast, the individual sounds and adjacent sounds in /wat/ occur in fewer words of the language. As early as 9 months of

age, children show sensitivity to the phonotactic probability of the ambient language (Jusczyk, Luce, & Charles-Luce, 1994). More importantly, this sensitivity to phonotactic probability appears to influence noun learning by preschool- and school-age children (Storkel, 2001; Storkel & Rogers, 2000). In particular, in Storkel (2001), 34 typically developing preschool children ($M = 4;6$ [years;months], $SD = 10$ months) were exposed to four nonwords composed of common sound sequences and four nonwords composed of rare sound sequences. The nonwords were paired with object referents and embedded in a story. Referent identification, form identification, and picture naming were measured across exposure to the nonwords to document learning. Across all three measures of learning, children responded more accurately to common than to rare sound sequences. In addition, the common sound sequence advantage in referent identification was larger for children with larger receptive vocabularies, suggesting an interplay between use of phonological regularities and size of the lexicon.

One limitation of the previous work on phonotactic influences on word learning is its focus on noun learning. The extant literature documents discrepancies between noun and verb learning. Specifically, naturalistic studies of early word learning in English have suggested that nouns predominate the early expressive and receptive lexicons (Bates, Dale, & Thal, 1995; Benedict, 1979; Bloom, Tinker, & Margulis, 1993; Goldin-Meadow, Seligman, & Gelman, 1976; Nelson, 1973b). Likewise, empirical studies that have systematically controlled frequency of exposure to nouns and verbs have provided evidence of a noun advantage in early word learning that continues into later stages of word learning. In one representative study, 12- to 15-month-old children who produced fewer than five words acquired more nouns than verbs when given equal exposure to both (Schwartz & Leonard, 1984). A similar result was obtained with 17- to 22-month-old children who produced between 25 and 75 words (Leonard et al., 1982). Likewise, during the preschool years, children tend to learn more nouns than verbs when given equal exposure to both (Rice, Buhr, & Nemeth, 1990; Rice, Oetting, Marquis, Bode, & Pae, 1994; Rice & Woodsmall, 1988). There are a number of different accounts for this apparent noun advantage, which differentially focus on conceptual versus input differences across nouns and verbs (see Gentner & Boroditsky, 2001, for review). The relevant conclusion for this study, however, is that noun learning differs from verb learning. Thus, the impact of phonological regularities on word learning may differ across nouns and verbs.

This hypothesis that the influence of phonological regularities on lexical acquisition may be modified by grammatical class is consistent with certain theories of word learning, namely the emergentist coalition model

(Hollich et al., 2000). According to this model, children are sensitive to multiple attentional, social, and linguistic cues and differentially rely on these cues across developmental time. Although this model typically focuses on changes in the use of cues across development, it also suggests the possibility that the influence of certain cues may differ across word-learning contexts. For example, past research has demonstrated that different types of cues are relevant depending on the type of noun being learned. Specifically, the relevant cue when learning count nouns seems to be the shape of the object, whereas the relevant cue when learning mass nouns seems to be the material of the object (e.g., Soja, 1992). In this case, the relevant perceptual cue for word learning, namely shape versus material, varied depending on the type of noun being learned. From this same perspective then, it is possible that the cues that are important for noun learning may not be the same cues that are useful for verb learning. As a first step toward addressing this issue, it is important to establish whether the distributional regularities that influence noun learning also influence verb learning.

The purpose of the current study was to examine the effect of phonotactic probability on verb learning to determine whether phonological cues for word learning are weighted similarly across words differing in grammatical class. Previous studies of noun learning have provided evidence that common sound sequences are learned more rapidly than rare sound sequences (Storkel, 2001; Storkel & Rogers, 2000). If this same common sound sequence advantage is observed for verbs, then the effect of phonotactic probability may be robust across grammatical class. This would indicate that phonological cues exert a similar influence on noun and verb learning. In contrast, if a null result is obtained, then this may indicate that phonological regularities only influence the acquisition of certain types of words. Distributional regularities that are relevant for word learning may be differentially weighted depending on the grammatical class of the word being acquired. Future work then would need to examine which cues are relevant for nouns versus verbs and when children develop the ability to differentially rely on word-learning cues across grammatical class. In addition, given the previous report of an association between the common sound sequence advantage in noun learning and vocabulary size, it may be important to examine whether a similar association is found in verb learning to provide further evidence regarding the interplay between cue use and size of the lexicon. To address these issues, verb-learning data were collected from preschool children similar in age and ability to those in the previous noun-learning study (Storkel, 2001). Methods for this study paralleled those of the noun-learning study. These new data were then analyzed and compared to the previous noun-learning data

(Storkel, 2001) to examine similarities and differences between noun and verb learning.

Method

The methods used in the current study directly paralleled the previous study of nouns (Storkel, 2001) to afford comparisons between the two studies. The only departures from the previous protocol related to the use of updated standardized tests (see the *Participants* section), the change from object to action referents (see the *Stimuli* section), and the inclusion of a baseline test condition (see the *Procedures* section).

Participants

Monolingual native English-speaking preschool children were recruited from the community surrounding Lawrence, Kansas, through newspaper advertisements, fliers, and letters to parents. Thirty-four typically developing children (14 boys and 20 girls) between the ages of 3;2 and 6;4 ($M = 4;3$, $SD = 8$ months) participated. This number and age range parallels that of the previous noun-learning study (Storkel, 2001). Hearing, vocabulary, and productive phonology were evaluated to verify that children were typically developing (American Speech-Language-Hearing Association [ASHA], 1997; Dunn & Dunn, 1997; Goldman & Fristoe, 2000; Williams, 1997). All children passed the hearing screening and demonstrated age-appropriate vocabulary and productive phonology. In terms of vocabulary, mean performance was at the 75th percentile ($SD = 19$, range = 25th–98th percentile) on the Peabody Picture Vocabulary Test–Third Edition (PPVT-III; Dunn & Dunn, 1997) and at the 76th percentile ($SD = 20$, range = 13th–98th percentile) on the Expressive Vocabulary Test (EVT; Williams, 1997). These scores parallel those of the children in the earlier noun-learning study (Storkel, 2001).

It should be observed that there was a wide range of performance on these standardized vocabulary tests, allowing for the examination of the relationship between standardized test performance and the magnitude of the effect of phonotactic probability on word learning. In addition, the tendency for participants to score in the above-average range on these standardized vocabulary tests should be noted because of the implication for generalizing these results to children with lower vocabulary scores. Relative to productive phonology, mean performance was at the 68th percentile ($SD = 20$) on the Goldman-Fristoe Test of Articulation–Second Edition (GFTA-2; Goldman & Fristoe, 2000). In addition, each child's production of the target consonants used in the stimuli was evaluated using the GFTA-2 and a supplemental probe. The supplemental probe sampled each target consonant in the relevant context, word-initial or word-final position, in a familiar real word. Production of the words was elicited via picture naming. Correct production of the target consonants was required to guard against misarticulation of the stimuli.

Stimuli

Nonwords

The same eight consonant–vowel–consonant (CVC) nonwords used by Storkel (2001) served as the target nonwords to be learned. Table 1 displays the stimuli. Extensive details concerning the construction of these nonwords can be found in Storkel (2001). Briefly, half of the nonwords comprised common sound sequences and half comprised rare sound sequences. Phonotactic probability was determined using two measures: positional segment frequency and biphone frequency. *Positional segment frequency* is the likelihood of occurrence of a given sound in a given word position. *Biphone frequency* is the likelihood of co-occurrence of two adjacent sounds. These two frequency counts were determined using a 20,000 word online dictionary (Nusbaum, Pisoni, &

Table 1. Form and action referent characteristics of the stimuli.

| Common sound sequence | Positional segment frequency | Biphone frequency | Rare sound sequence | Positional segment frequency | Biphone frequency | Argument structure | Action 1 | Action 2 |
|-----------------------|------------------------------|-------------------|---------------------|------------------------------|-------------------|--------------------|---|--|
| wæt | 0.1657 | 0.0066 | naub | 0.0595 | 0.0004 | Transitive | Carry object on head (Sendak, 1962b, p. 47) | Move object with pole (Sendak, 1962a, p. 23) |
| hʌp | 0.1157 | 0.0036 | gim | 0.1072 | 0.0013 | Transitive | Pour substance on head (Sendak, 1962b, p. 13) | Spray substance (Sendak, 1962b, p. 35) |
| pin | 0.2123 | 0.0053 | mɔɪd | 0.0986 | 0.0004 | Intransitive | Shrink down to floor (Sendak, 1962b, p. 27) | Float up in air (Sendak, 1970, p. 8) |
| koof | 0.1617 | 0.0066 | jeɪp | 0.0742 | 0.0018 | Intransitive | Stand on head (Sendak, 1962b, p. 23) | Dance on one foot (Sendak, 1962b, p. 45) |

Davis, 1984). Computations were blind to the grammatical class of the words in the online dictionary because previous comparisons of the phonology of nouns versus verbs have failed to detect consistent differences in segmental phonology, although reliable differences in duration, word length, and stress have been documented (Cassidy & Kelly, 1991; Kelly & Bock, 1988; Sereno, 1986; Sereno & Jongman, 1990; Sorenson, Cooper, & Paccia, 1978). Given this lack of difference in segmental phonology, phonotactic probability is likely to be similar across nouns and verbs. Common sound sequences were differentiated from rare sound sequences by dividing all possible CVCs at the median positional segment and biphone frequencies. The selected CVCs were phonologically dissimilar to one another and comprised early acquired consonants to guard against misarticulation (Smit, Hand, Freilinger, Bernthal, & Bird, 1990).

Referents

The right-hand columns of Table 1 describe the eight action referents that were paired with the nonwords. Action referents were adapted from children's stories and had no agreed upon single-word label in the English language. This was validated by having 6 adults generate a verb for each action. On average, only 51% (range = 25%–60%) of the adults produced the same verb for each action. Thus, adults did not appear to agree upon the verb label for the picture referent, suggesting that the action referents were not typical actions with strong associations to existing verbs. In addition, actions were selected in syntactic pairs based on similarity in the arguments required, namely transitive versus intransitive verbs. Argument structure of the nonword verbs was maintained consistently throughout exposure as described in the Story section below. Within each syntactic pair, one referent was randomly assigned a common sound sequence and the other, a rare sound sequence. Nonword referent pairings were counterbalanced across participants.

Story

A story consisting of three episodes was created. Each episode focused on two main characters performing a series of tricks for a different audience (e.g., children, parents). Scenes from children's picture books (Sendak, 1962a, 1962b, 1970) were combined and adapted to make a cohesive story episode. Each episode began with a picture introducing the characters. The subsequent four pictures depicted the two main characters performing each of the syntactically paired actions. The final picture showed the characters again and concluded the story line. The story pictures were 8 × 11 in. color drawings placed in a story book.

A story narrative was created to provide the auditory exposure to the nonwords. Each episode began with several introductory sentences that identified the main characters and the scene. Then the target nonwords were presented in a sentence context. Exposure sentences for each nonword within a syntactic pair were virtually identical. All nonword verbs were presented in uninflected form and always occurred with the same agent. Transitive nonword verbs always occurred with the same direct object. Intransitive nonword verbs never occurred with a direct object. The number of exposures to a given nonword varied across episodes, with 1 exposure in Episode 1 and 3 exposures in Episodes 2 and 3. A sample of the exposure sentences is given in the Appendix. Each episode ended with a concluding sentence to introduce a delay between exposure and test. A female speaker recorded two versions of the story corresponding to the counterbalanced nonword–referent pairings.

Measures of Learning

The same measures of learning used in the previous noun-learning study (Storkel, 2001) were used in the current verb-learning study.

Referent Identification

In this three-alternative forced-choice task, the child heard a prerecorded nonword (e.g., /wæt/) and selected the picture of the corresponding referent from a field of three pictures. The three choices included the target referent (e.g., lion carrying object on head), the syntactically paired alternative (e.g., boy moving object with pole), and an unrelated referent also presented in the story (e.g., lion dancing on one foot). The order of the picture choices was randomized across trials. The relationship between the target and the unrelated referent freely varied in terms of phonotactic probability and the agent performing the action.

Form Identification

In this three-alternative forced-choice task, children saw a picture of one novel action (e.g., lion carrying object on head) and selected the corresponding nonword label from a field of three auditory alternatives. Each auditory alternative was presented sequentially and paired with a white square. The child then pointed to the square corresponding to his or her response. The three alternatives paralleled those of the referent identification task: target (e.g., /wæt/), syntactic pair (e.g., /naʊb/), unrelated (e.g., /jeɪp/). The presentation order of the auditory alternatives was randomized across trials.

Picture Naming

In this task, children saw a picture of one of the novel actions (e.g., lion carrying object on head) and attempted to spontaneously produce the nonword label. Responses were audio recorded and phonetically transcribed. Consonant-to-consonant transcription reliability, computed for 21% of the sample, was 96.4% ($SD = 4.55$). Responses then were scored using lenient criteria. A response was scored as correct if it contained two of three correct phonemes in the correct word position (e.g., [wæk] for target /wæt/). Child productions that formed either real words or other nonwords were scored in the same way, with no differentiation of real versus nonword responses in keeping with the procedures of Storkel (2001). Importantly, real word responses tended to be phonologically related but not semantically related to the target (e.g., [kout] for target /kouf/ depicting a lion performing a dancing action). A greater proportion of responses scored as common sound sequence targets formed real words ($M = 0.31$, $SD = 0.25$) compared to those scored as rare sound sequence targets ($M = 0.06$, $SD = 0.05$). This is to be expected given the positive correlation between phonotactic probability and neighborhood density (Vitevitch, Luce, Pisoni, & Auer, 1999). That is, common sound sequences are phonologically similar to many other words in the language, whereas rare sound sequences are phonologically similar to few other words in the language. As a result, changing one sound in a common sound sequence is more likely to result in the creation of a real word than will changing one sound in a rare sound sequence. The interested reader is referred to Storkel and Rogers (2000) for a full discussion of the implication of this correlation for word learning.

Procedures

Each child participated in three sessions that occurred at Indiana University, the University of Kansas, or a local preschool. Children who traveled to the university to participate were paid \$5 per session. In all cases, testing was conducted in a quiet room with the examiner and child seated at a table. In the first session, the GFTA-2 and the hearing screening (ASHA, 1997) were administered. In addition, the supplemental phonological probe was administered to examine each child's articulation of the target consonants used in the nonwords. Each child was required to produce the target consonants in the target word position in both the GFTA-2 and the supplemental phonological probe samples. All children met this criterion.

In the second session, occurring approximately 1 week later, each child participated in the word-learning task. All auditory stimuli were presented via a digital audiotape deck and tabletop speakers at a comfortable

listening level. Baseline testing on the measures of learning was conducted for each nonword prior to story exposure. Referent identification testing was conducted first, followed by form identification and then picture naming. To introduce the referent identification task, the child was told "I'm going to say a word. Point to the picture that you think goes with the word." Three real words then were tested to ensure that the child understood the task. The child was required to answer two of the three training items correctly. All children passed this pretraining. Then the child was told "Now I'm going to show you some funny pictures that we'll see in our story. I'm going to play a funny word. Try and guess which picture goes with the funny word." The nonword items were then administered and the child was encouraged to guess.

The form identification task then was administered with a training task involving real words. The child was told "Here's a picture. I'm going to say three choices for its name. You point to the one you think is right. You can pick this one, this one, or this one [examiner pointing to each square in turn]. Ready. Listen." Three real words were tested to ensure that the child could perform the task. The child was required to answer two of the three training items correctly. All children passed this pretraining. Then the child was told "Now I'm going to show you the funny pictures we'll see in the story and play the funny words. Try and guess what word goes with the picture." The nonword items were then administered.

Baseline testing was not conducted for the picture naming task because it was assumed that children would not name any of the pictures with the correct nonword. Production of the nonwords was elicited in imitation to ensure that children correctly articulated the nonwords. All children correctly articulated the nonwords.

After completing baseline testing, the child listened to the first story episode, which provided 1 exposure of each of the eight nonwords. The measures of learning were then re-administered in the same order following the same procedures detailed above. The instructions to the child were modified from encouraging the child to guess to encouraging the child to remember the items from the story (e.g., "Now I am going to show you the pictures from the story and play you a word from the story. Try and remember which picture goes with the word from the story"). The child then listened to the second story episode, which provided 3 exposures to all eight nonwords. The measures of learning were re-administered. Finally, the child listened to a third story episode that provided 3 exposures to the nonwords. The measures of learning were re-administered. The entire protocol was completed in approximately 45 min.

The child then returned for the third session approximately 1 week postexposure ($M = 7$ days, $SD = 2$,

range = 3–14 days). At this time, the measures of learning were re-administered to examine retention of stimuli. The PPVT-III and the EVT also were administered.

Results

Reliability

Consonant-to-consonant transcription reliability was computed for 21% of the GFTA-2 and phonological probe samples. Transcription reliability was 95.5% ($SD = 2.75$). Scoring reliability for the picture naming task was computed for 18% of the sample and was 97.9% ($SD = 3.78$).

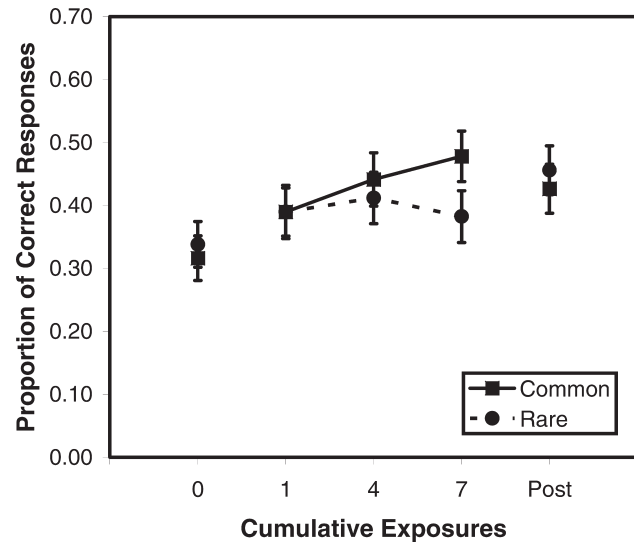
Verb-Learning Accuracy Analysis

A separate analysis of accuracy was performed for each measure of learning: referent identification, form identification, and picture naming. Proportion of correct responses collapsed across individual nonwords served as the dependent variable. These proportions were submitted to a 2 (phonotactic probability: common vs. rare) \times 4 (exposures: 1 vs. 4 vs. 7 vs. 1 week post-exposure) repeated-measures analysis of variance (ANOVA) with Huyhn–Feldt correction for sphericity (Huynh & Feldt, 1976). Two effect sizes were computed for each independent variable: f^2 and the proportion of variance accounted for by a given variable (PV). Conventional guidelines were used to interpret these effects as small, medium, or large (Cohen, 1988). Note that responses at baseline (0 exposures) were not included in the ANOVA so that it would parallel the methods in the previous study of noun learning (Storkel, 2001). Baseline performance was used in two additional analyses. The first analysis compared responses to common versus rare sound sequences at baseline using a paired t test to determine whether response biases existed prior to exposure. The second analysis compared performance at baseline to performance at each level of exposure using paired t tests and Bonferroni correction for multiple comparisons to determine when performance was significantly different from baseline, assuming that baseline performance was equivalent to chance responding.

Referent Identification

Accuracy analysis for the referent identification task showed no significant effects ($F < 1.30$, $p > .27$). Moreover, effect sizes for each variable were small ($f^2 < 0.05$, $PV < .05$). Figure 1 shows the proportion correct for common versus rare sound sequences following 0, 1, 4, and 7 cumulative exposures, as well as 1 week postexposure.

Figure 1. Mean proportion of correct responses in the referent identification task for common (squares) versus rare (circles) sound sequences following 0, 1, 4, and 7 exposures and 1-week postexposure. Error bars represent standard error. Chance performance is referenced by 0 exposures (baseline).

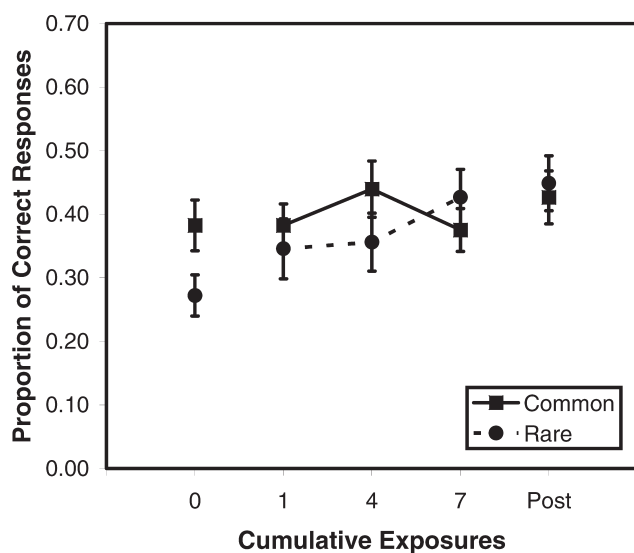


Analysis of baseline (0 exposure) performance showed no significant difference between common and rare sound sequences prior to exposure, $t(33) = 0.44$, $p = .66$. Thus, no response bias appeared to exist a priori. A comparison between performance at baseline and performance at each exposure provides evidence of a potential advantage for common over rare sound sequences. The difference in referent identification of common sound sequences between baseline and 4 exposures approached significance, $t(33) = -2.57$, corrected $p = .06$. In addition, the difference between baseline and 7 exposures was significant, $t(33) = -3.35$, corrected $p = .008$. Referent identification of rare sound sequences, however, was never significantly different from baseline ($t < -2.27$, corrected $p > .11$).

Form Identification

Accuracy analysis for the form identification task showed no significant effects ($F < 1.37$, $p > .25$). Moreover, effect sizes for each variable were small ($f^2 < 0.05$, $PV < .05$). Figure 2 shows the proportion correct for common versus rare sound sequences across exposures. The difference between common and rare sound sequences at baseline approached significance, $t(33) = -1.81$, $p = .08$. Children provided more correct responses to common than to rare sound sequences prior to exposure, suggesting a potential response bias. Form identification of common sound sequences was never significantly different from this high baseline performance ($t < 0.97$, corrected $p = 1.00$). In contrast, form identification of rare

Figure 2. Mean proportion of correct responses in the form identification task for common (squares) versus rare (circles) sound sequences following 0, 1, 4, and 7 exposures and 1-week postexposure. Error bars represent standard error. Chance performance is referenced by 0 exposures (baseline).

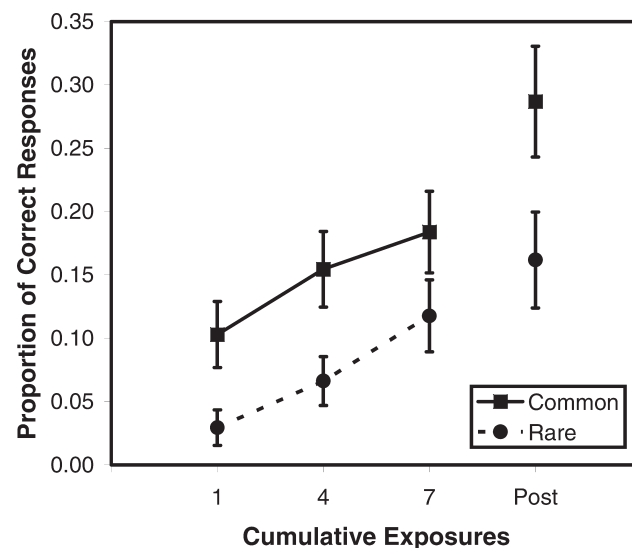


sound sequences was significantly better than baseline performance following 7 exposures and 1 week postexposure, $t(33) = -2.87$, corrected $p = .03$; $t(33) = -3.78$, corrected $p = .004$, respectively. Given the high accuracy for common sound sequences at baseline, results from the form identification task should be interpreted with caution.

Picture Naming

An ANOVA showed a main effect of phonotactic probability, $F(1, 33) = 12.01$, $p = .001$, and a main effect of exposure, $F(3, 99) = 17.03$, $p < .0001$. The interaction of phonotactic probability and exposure failed to reach significance, $F(3, 99) = 0.75$, $p = .49$. Figure 3 shows the proportion of correct responses in the picture naming task. The common sound sequences were named more accurately than the rare sound sequences. Phonotactic probability accounted for 27% of the variance in picture naming, indicating a large effect on performance ($f^2 = 0.36$). In addition, performance had a tendency to increase across exposures, as indicated by a significant linear trend, $F(1, 33) = 42.70$, $p < .0001$. The number of exposures accounted for 30% of the variance in picture naming, indicating a large effect on performance ($f^2 = 0.43$). Baseline comparisons were not performed because children were not given the opportunity to spontaneously name the novel actions at baseline. It is important to note that 6 children showed floor performance in this task, as indicated by 0% accuracy across all exposures. This number is similar to that found in the

Figure 3. Mean proportion of correct responses in the picture naming task for common (squares) versus rare (circles) sound sequences following 1, 4, and 7 exposures and 1-week postexposure. Error bars represent standard error.



previous study of noun learning (Storkel, 2001), where 6 children also showed floor performance in the picture naming task. As in the noun-learning study, inclusion of these children in the statistical analyses did not appear to influence the outcomes, as indicated by similar p values when the same analyses were performed on the data excluding these children at floor level.

Verb-Learning Correlation Analysis

Results from the ANOVAs and t tests showed that preschool children tended to learn common sound sequences more rapidly than rare sound sequences in the referent identification and picture naming tasks. This common sound sequence advantage may be influenced by age, vocabulary development, or phonological acquisition. To explore this possibility, a mean difference score between common and rare sound sequences (i.e., accuracy-common – accuracy-rare) was computed for each child in each task and submitted to a correlation analysis with age and raw scores on standardized tests. Difference scores derived from the referent identification task were not significantly correlated with raw scores on the PPVT-III, EVT, and GFTA-2, or with chronological age ($r < .21$, $p > .25$). Similarly, form identification and picture naming difference scores were not significantly correlated with standardized test performance or age ($r < .28$, $p > .11$). Thus, the common sound sequence advantage did not appear to increase or decrease with advances in vocabulary, productive phonology, or age.

It is possible that the standardized vocabulary tests used do not adequately measure the verb lexicon. To address this issue, a measure of overall performance was computed by determining the mean performance of each participant across each Phonotactic Probability \times Exposure condition. Mean performance in the referent identification task was significantly correlated with raw scores on the PPVT-III, $r(34) = .515, p = .002$, and raw scores on the EVT, $r(34) = .580, p < .001$. As in the referent identification task, mean performance on the picture naming task was significantly positively correlated with raw scores on the PPVT-III, $r(34) = .498, p = .003$, and raw scores on the EVT, $r(34) = .412, p = .016$. Children with higher standardized test scores learned more nonwords in the study. Thus, these standardized tests did predict overall verb learning but not the common sound sequence advantage.

Comparison to Noun-Learning Study (Storkel, 2001)

Finally, the data from the previous study of noun learning (Storkel, 2001) were combined with the current study of verb learning to examine the effect of grammatical class on word learning. A 2 (grammatical class: noun vs. verb) \times 2 (phonotactic probability: common vs. rare) \times 4 (exposures: 1 vs. 4 vs. 7 vs. 1 week postexposure) repeated-measures ANOVA was performed on the combined data set. This analysis showed no significant main effect of grammatical class in any task (all F s $< 1.30, p > .27$). Thus, the predicted noun advantage was not observed in any measure of word learning. Furthermore, there was no significant interaction of grammatical class and phonotactic probability in the referent identification and picture naming tasks (all F s $< 2.17, p > .14$). The only task showing a significant interaction of grammatical class and phonotactic probability was the form

identification task, $F(1, 63) = 8.48, p = .005$. For form identification, there was a significant effect of phonotactic probability for nouns only.

Discussion

The purpose of the current study was to examine the influence of word-learning cues across words differing in grammatical class. Previous studies of noun learning provided evidence of an advantage for common sound sequences over rare sound sequences across multiple measures of learning (Storkel, 2001; Storkel & Rogers, 2000). Additional work has suggested that nouns were learned more rapidly than verbs, implying that word-learning cues may differentially influence learning depending on the grammatical class of the novel words. The current results afford an important comparison between noun and verb learning; this comparison has implications for the emergentist coalition model and understanding the noun-verb difference. Each issue is now considered in turn.

Comparison to Noun Learning

Table 2 provides a comparison of the previous noun-learning results (Storkel, 2001) with the current verb-learning results. Across the two studies, the results are quite similar. In referent identification and picture naming tasks, common sound sequences were learned more rapidly than rare sound sequences regardless of the grammatical class of the words being acquired. This same common sound sequence advantage was not observed in the form identification task with verbs, but the analysis of the baseline condition in this task suggested that children might be biased to select common sound sequences prior to exposure. As a result, the form

Table 2. Comparison of findings from a previous noun-learning study and the current verb-learning study.

| | Noun study results (Storkel, 2001) | Verb study results |
|--------------------------------|---|---|
| Accuracy analysis ^a | | |
| Referent identification | Common > rare; medium effect | Common > rare; small effect |
| Form identification | Common > rare; large effect | Common > rare at baseline; response bias? |
| Picture naming | Common > rare; medium effect | Common > rare; large effect |
| Correlation analysis | | |
| Referent identification | Difference score correlated with PPVT-R | No significant correlation |
| Form identification | No significant correlation | No significant correlation |
| Picture naming | No significant correlation | No significant correlation |

Note. PPVT-R = Peabody Picture Vocabulary Test-Revised.

^aStorkel (2001) also examined error patterns. Error patterns were similar across the earlier noun study and the current verb study. Refer to Storkel (2001) for details.

identification results are set aside and discussed more fully under caveats. Thus, the accuracy analyses provided evidence that phonotactic probability influenced learning of both nouns and verbs.

Correlation analysis suggested a slight departure between the noun- and the verb-learning results. In particular, the difference between common and rare sound sequences in noun learning increased as receptive vocabulary increased. In contrast, no significant correlation was found between the common-rare sound sequence difference in verb learning and receptive vocabulary. One possible account of this difference relates to the magnitude of the effect of phonotactic probability across the noun and verb studies. Specifically, phonotactic probability had a medium effect on referent identification of nouns but a small effect on referent identification of verbs. Therefore, the mean difference between common and rare sound sequences in the noun study was accentuated when compared to the verb study. As a result, any association between this difference and vocabulary development may not have been sufficiently large to be detected in the verb study. A second possibility may relate to the change in the instrument used to measure vocabulary development. The noun study used the Peabody Picture Vocabulary Test-Revised, whereas the verb study used the PPVT-III. These two instruments may differentially tap phonotactic probability. A third possible account is that the influence of phonotactic probability on verb learning may be relatively consistent throughout vocabulary acquisition. Additional research is needed to differentiate among these alternatives.

Implication for the Emergentist Coalition Model

The emergentist coalition model predicts that children use multiple cues to learn new words and that cue use may vary across different types of words. The finding of a similar effect of phonotactic probability on noun and verb learning suggests that the use of phonological regularities may be robust across words differing in grammatical class. That is, the influence of phonological cues on word learning appeared to be relatively consistent across grammatical class in preschool word learners. This suggests that children may use the same cues to learn nouns and verbs despite overall differences in the rate of acquisition of these two types of words. One reason why regularities in segmental phonology may have a similar influence on noun and verb learning is that segmental phonology is relatively consistent across grammatical class. That is, previous comparisons of the segmental phonology of nouns versus verbs have failed to detect consistent and systematic differences in the sound structure of nouns versus verbs (Cassidy & Kelly,

1991; Kelly & Bock, 1988; Sereno, 1986; Sereno & Jongman, 1990; Sorenson et al., 1978). Thus, segmental phonology does not appear to vary by grammatical class, so the relevance of this cue may be consistent across noun and verb learning. In contrast, other types of cues may vary systematically by grammatical class, and thus the relevance of these cues for noun versus verb learning may differ. For example, morphological cues might be less critical for noun than verb learning because of differences in inflectional morphology between nouns and verbs in English. In this case, children may rely more heavily on inflectional cues for verb learning than for noun learning. Future investigation is needed to determine how cue consistency may relate to asymmetries in cue use across words differing in grammatical class as a means of further elucidating the underlying mechanisms governing cue use in the emergentist coalition model.

Although consistent use of phonological cues across noun and verb learning was observed, it is still possible that children may weight phonological cues differentially by grammatical class in less-constrained word-learning contexts. In these laboratory studies, many attentional, social, and linguistic cues were tightly controlled and equated across noun and verb learning. It is possible that when these cues are free to vary, differences in the influence of phonological cues by grammatical class will arise. This suggests the possibility that the influence of various cues may differ across word-learning contexts depending on the number and type of cues that are available to support word learning.

Implication for Noun-Verb Difference

The finding of similar rates of learning across nouns and verbs represents a departure from previous studies. Understanding this discrepancy across studies may provide insights into the reported noun-verb difference in acquisition. One important difference between the current study and previous work is the level of experimental control. In particular, across the two studies, nouns and verbs occurred with equal frequency during the exposure phase of the word-learning paradigm, the exact same methods of exposure and testing were used across nouns and verbs, and the exact same sound sequences were used as labels for both objects and actions. Although a number of studies have used the first two experimental controls (Leonard et al., 1982; Rice et al., 1990; Rice & Woodsmall, 1988; Schwartz & Leonard, 1984), few studies have attempted to equate the phonological characteristics of the nouns and verbs to be learned. That is, in most studies of the noun-verb difference, the nouns and verbs differ in both grammatical

class and phonological composition. Differences in phonological control may account for the discrepancy in the findings across studies.

Another factor that may account for the similar rate of learning for nouns and verbs in this series of studies may be that the nonwords were actually more “verb-like” than “noun-like.” These two studies used monosyllabic nonwords. Previous research has indicated that nouns typically have more syllables than verbs (Cassidy & Kelly, 1991). Thus, nouns are more likely to be multisyllabic, and verbs are more likely to be monosyllabic. Moreover, this difference in number of syllables appears to influence language processing and word learning (Cassidy & Kelly, 1991, 2001). When word length cues are consistent with grammatical class, learning is facilitated relative to a condition when cues are inconsistent (Cassidy & Kelly, 2001). In the noun study, the word length cues to grammatical class may not have converged with semantic and syntactic cues for grammatical class; however, in the verb study, word length, semantic, and syntactic cues for grammatical class likely did converge. This difference in cue convergence may have favored verbs over nouns, allowing conceptual and input differences, which disfavor verbs, to be overcome. As a result, a similar rate of learning for nouns and verbs would be expected.

A final factor that may account for the variability in the noun–verb difference across studies relates to study design. In these two studies, the noun–verb comparison was made across studies and, therefore, between participants. Thus, children were only exposed to nouns or verbs but not both in tandem. In most studies, the noun–verb comparison has been made within participants (Leonard et al., 1982; Rice et al., 1990; Rice & Woodsmall, 1988; Schwartz & Leonard, 1984). That is, each participant was exposed to both nouns and verbs simultaneously. Thus, it is possible that the noun advantage over verbs may only emerge when noun and verb learning are pitted against one another, as would be the case in simultaneous presentation. It is important to note that naturalistic word learning likely entails exposure to both novel nouns and novel verbs in tandem. The findings from empirical studies using simultaneous presentation may be more representative of word learning in naturalistic contexts.

Caveats

The inclusion of a baseline condition in the current study provided an important validation of the word-learning paradigm that was used. One finding that emerged was that responses to common sound sequences were significantly more accurate than responses to rare sound sequences at baseline in the form identification

task. When asked to choose the label of an unfamiliar action, children were biased to select a common over a rare sound sequence prior to exposure. Children may assume that the most likely label for a novel action is a common sound sequence rather than a rare sound sequence. As a result, the form identification task may not be a valid measure of word learning when the words to be learned vary in phonotactic probability. Studies using a form identification task as a measure of word learning may need to control the phonotactic probability across the relevant levels of the independent variable to ensure that the task is a valid measure of learning.

Another important methodological issue is that referent identification and picture naming tests yielded slightly different results across both the noun- and verb-learning studies. In particular, the accuracy difference between common and rare sound sequences was reduced at the 1 week postexposure referent identification test but was enlarged at the postexposure picture naming test. Likewise, phonotactic probability effect sizes in both studies were smaller for referent identification than for picture naming. These observations suggest that referent identification tasks may be less sensitive than picture naming tasks to the influence of phonological regularities on word learning, especially at retention. This asymmetry in sensitivity across tasks may be related to differential reliance on phonological forms. Specifically, in the referent identification task, the child is given the phonological form and must select the referent. In this case, the child may be able to make a correct response even if his or her mental representation of the phonological form is incomplete or inaccurate. In the picture naming task, the child is given the referent and must access the mental representation of the phonological form. If this representation is incomplete, inaccurate, or inaccessible, then the child is likely to produce no response or an inaccurate response. In this way, referent identification performance is influenced less by the completeness and accuracy of the mental representation of the phonological form than picture naming is. In studies examining the influence of phonological characteristics on word learning, use of a picture naming task, rather than a referent identification task, may represent a stronger test of the motivating hypothesis.

The results of the current study of verb learning replicate and extend previous studies of noun learning. Previous work has shown a significant effect of phonotactic probability on noun learning. The current study provides evidence that this effect of phonotactic probability extends to verb learning. Thus, the mechanisms that underlie noun and verb learning appear similar in terms of the influence of phonological cues on word learning. The results further indicate a need to consider phonological characteristics when comparing noun and verb learning.

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Appendix. Sample exposure for transitive verb.

| | Common sound sequence | Rare sound sequence |
|-------------------------|--|--|
| Episode 1 (1 exposure) | Lion said, "Wait 'til you see what I'm gonna do next." The little boy said, "Watch me first. I'm going to /pin/." | Lion said, "Now watch me. I'm going to /mɔɪd/." |
| Episode 2 (3 exposures) | The little boy said "This is an awesome trick." "I can /pin/. Can you /pin/?" The kids said "I wish I could /pin/" | Lion said "Watch me." "I can /mɔɪd/. Can you /mɔɪd/?" The kids said "I wish I could /mɔɪd/." |
| Episode 3 (3 exposures) | The little boy said "OK. Here's the first trick, watch closely." "See I can /pin/." Mom yelled, "No don't /pin/. That's dangerous. Don't ever /pin/ again!" | Lion said, "My turn." "See I can /mɔɪd/." Dad yelled, "No don't /mɔɪd/. That's dangerous. Don't ever /mɔɪd/ again!" |

Note. Exposure sentence(s) for common sound sequences were followed by those for rare sound sequences for this action pair. The order of exposure sentences for common versus rare sound sequences was counterbalanced across action pairs and across participants.