Journal of Experimental Child Psychology 114 (2013) 405–417

Contents lists available at SciVerse ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Learning about sounds contributes to learning about words: Effects of prosody and phonotactics on infant word learning

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ARTICLE INFO

Article history:
Received 16 May 2012
Revised 4 October 2012
Available online 22 November 2012

Keywords:
Language acquisition
Phonological development
Word learning
Statistical learning
Prosody
Phonotactics
Infancy

ABSTRACT

This research investigates how early learning about native language sound structure affects how infants associate sounds with meanings during word learning. Infants (19-month-olds) were presented with bisyllabic labels with high or low phonotactic probability (i.e., sequences of frequent or infrequent phonemes in English). The labels were produced with the predominant English trochaic (strong/weak) stress pattern or the less common iambic (weak/strong) pattern. Using the habituation-based Switch Task to test label learning, we found that infants readily learned high probability trochaic labels. However, they failed to learn low probability labels, regardless of stress, and failed to learn iambic labels, regardless of phonotactics. Thus, infants required support from both common phoneme sequences and a common stress pattern to map the labels to objects. These findings demonstrate that early word learning is shaped by prior knowledge of native language phonological regularities and provide support for the role of statistical learning in language acquisition.

Introduction

Before uttering their first words, infants have learned a remarkable amount about the sound structure of their native language. Infants' speech perception becomes focused on the relevant phoneme contrasts for their language (e.g., Werker & Tees, 1984), and they learn how phonemes typically

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0022-0965/$ - see front matter
http://dx.doi.org/10.1016/j.jecp.2012.10.002

combine within words (e.g., Jusczyk, Luce, & Charles-Luce, 1994). Infants also learn native language rhythmic patterns and several cues for detecting words in fluent speech (e.g., Jusczyk, Cutler, & Redanz, 1993; reviewed in Saffran, Werker, & Werner, 2006). During the second year of life, infants make substantial progress in associating words with their referents and vocabulary development accelerates. A large literature has explored how young children acquire meanings for new words (reviewed in Waxman & Lidz, 2006), and a separate body of work has investigated how infants learn about phonology. However, we know relatively little about how the precocious learning about sound structure is linked to the process of associating sounds with meanings during word learning (e.g., Graf Estes, Edwards, & Saffran, 2011; Werker, Fennell, Corcoran, & Stager, 2002; reviewed in Saffran & Graf Estes, 2006). Understanding this connection is important for explaining how early learning provides a foundation for future learning. Infants detect many sound system regularities in the ambient language, but do these regularities affect learning of higher levels of linguistic structure such as words? In the current research, we addressed how early phonological development contributes to word learning by testing how native language prosodic and phonotactic patterns affect how infants learn new object labels.

Learning about prosody

Prosodic structure is one of the earliest linguistic characteristics that infants are sensitive to, and it remains highly salient through adulthood. Newborns can discriminate their native language from a foreign language based on rhythmic differences (e.g., Mehler et al., 1988; Nazzi, Bertoncini, & Mehler, 1998). Infants can also distinguish lexical stress patterns at very young ages (Jusczyk & Thompson, 1978; Sansavini, Bertoncini, & Giovanelli, 1997). Over time, language experience shapes how infants process lexical stress. For example, the predominant prosodic pattern of English words is trochaic; strong (stressed) syllables precede unstressed (weak) syllables (e.g., BAby, HAppy [capital letters indicate stress]). Iambic words, in which weak syllables precede strong syllables, are less frequent (e.g., guiTAR, toDAY). Between 6 and 9 months of age, English-learning infants develop a listening preference for bisyllabic words with trochaic (strong/weak) stress rather than iambic (weak/strong) stress, indicating that they have learned the common pattern (Jusczyk, Cutler, & Redanz, 1993).

Infants' attention to regularities in lexical stress patterns may help them to segment words in continuous speech. English-speaking adults use strong syllables to identify the beginnings of words in fluent speech (e.g., Cutler & Norris, 1988; McQueen, Norris, & Cutler, 1994), and infants do as well (e.g., Curtin, Mintz, & Christiansen, 2005; Echols, Crowhurst, & Childers, 1997; Morgan, 1996). For example, Jusczyk, Houston, and Newsome (1999) found that 7.5-month-olds segmented trochaic words from fluent speech, but they missegmented iambic words, treating the stressed second syllables as word-initial syllables. At 10.5 months, infants correctly segmented iambic words, possibly by integrating other segmentation cues. Furthermore, several experiments have found that infants weight stress cues more heavily than other segmentation cues, such as patterns of syllable co-occurrence probabilities, when the two cues conflict (Johnson & Jusczyk, 2001; see also Mattys, Jusczyk, Luce, & Morgan, 1999; Shukla, Nespor, & Mehler, 2007). This weighting seems to change over development, with younger infants relying more on syllable probabilities and older infants relying more on stress (Johnson & Seidl, 2009; Thiessen & Saffran, 2003).

Recent experiments have addressed how stress affects infants' representations of new words when they are associated with referents. Curtin (2009) found that English-learning 12-month-olds learned pairs of object labels that differed only in their stress patterns (e.g., *BEdoka* + Object 1 and *beDOka* + Object 2). The word forms were segmentally identical, yet infants treated them as separate labels (see also Curtin, 2010). Infants must learn to interpret lexical stress in their native language because languages vary in their use of stress to signify differences in meaning. For example, Spanish uses stress contrastively, but French does not (e.g., Peperkamp, Vendelin, & Dupoux, 2010). English contains some word pairs in which stress distinguishes meanings (e.g., DIScount vs. disCOUNT); however, contrastive stress patterns often indicate grammatical distinctions such as between nouns and verbs (see Cutler, 2008, for a review). A recent study by Curtin, Campbell, and Hufnagle (2012) indicates that infants learn how lexical stress aligns with different word types, which affects how they acquire new words. English-learning 16-month-olds heard bisyllabic labels for actions presented with trochaic or iambic stress. Consistent with the sound pattern of many English verbs (Kelly & Bock, 1988), infants associated iambic labels with the actions but did not associate trochaic labels with the actions. However, infants associated the trochaic labels with objects, consistent with their experience of most bisyllabic English nouns (Kelly & Bock, 1988). It seems that infants expect action labels to have iambic stress. It is not yet clear whether infants show a similar pattern of differentiation between iambic and trochaic stress patterns for object labels.

Floccia, Nazzi, Austin, Arreckx, and Goslin (2011) investigated how lexical stress interacts with the phonetic specificity of new words. They presented 20- to 24-month-old English-learning infants with minimal pair object labels that differed by a single phoneme at the start of the first or second syllable. The labels were all bisyllabic and produced with either iambic or trochaic stress. They were introduced in an interactive label-learning task. Floccia and colleagues found no overall advantage for processing the common trochaic pattern. How lexical stress affects learning of labels that differ by more than a single phoneme remains to be established; because of the demands of attending to precise phonetic detail while associating words with referents, one cannot assume that the processes of learning minimal pair labels and more phonetically distinct labels are equivalent (e.g., Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Werker et al., 2002). Floccia and colleagues (2011) also reported that infants were better at detecting phonemic detail (i.e., the single phoneme difference) in stressed syllables than in unstressed syllables regardless of syllable position. The effect of stress on phonemic detail detection illustrates one way in which prosodic information affects how infants process phonemic information in new words. We have not yet identified the full range of ways in which phonemic and prosodic information interact.

Learning about phonotactics

During the period when infants learn about prosodic regularities, they also learn about native language phonemic regularities, including phonotactic information. The phonotactic patterns of a language include the constraints on how phonemes can be combined within words as well as probabilistic information regarding the frequency of occurrence of phonemes and phoneme combinations (Vitevitch & Luce, 2004). At 9 months of age, infants can discriminate between phoneme sequences that occur within native-language words (termed "legal" sequences) and those that do not (termed "illegal" sequences) (Friederici & Wessels, 1993; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993). In addition, 9-month-olds, but not 6-month-olds, are sensitive to the fine-grained distinction between words that are legal but have high phonotactic probability (i.e., they contain frequent phonemes and phoneme combinations) versus low phonotactic probability (i.e., they contain infrequent phonemes and phoneme combinations) (Jusczyk et al., 1994). For example, Jusczyk and colleagues (1994) found that 9-month-olds preferred high phonotactic probability word lists such as bIs (biss), dɛp (dep), and kæg (kag) over low probability lists such as jɔtʃ (yawch), taʊdʒ (touj), and guʃ (goosh). Similar to the findings for lexical stress (Jusczyk et al., 1999), between 6 and 9 months of age, infants develop a preference for listening to sound sequences that are consistent with the patterns of many native language words.

Like prosody, phonotactics provides cues to word boundaries in speech. Adults recognize words more rapidly when the junction between two words forms a phoneme cluster that does not typically occur within words (e.g., McQueen, 1998; Weber & Cutler, 2006). For example, knowledge of English phonotactics should help listeners to detect a word boundary when they encounter a phoneme sequence such as *db* (e.g., bad boy) because *db* does not occur word-initially or word-finally in English. Mattys and Jusczyk (2001) reported that, like adults, 9-month-olds use phonotactic segmentation to detect words. However, 9-month-olds also weight stress cues to word boundaries more heavily than phonotactic cues when the two conflict (Mattys et al., 1999).

In addition to their role in word segmentation, phonotactic regularities may shape lexical development by affecting how children learn new object labels. Graf Estes and colleagues (2011) found that 18-month-olds' learning was affected by native language phonotactic constraints on acceptable word forms. Infants readily learned novel object labels that consisted of legal phoneme combinations in English, but they failed to learn labels that contained illegal phoneme combinations. MacKenzie, Curtin, and Graham (2012) also found that 12-month-olds failed to learn phonotactically illegal object labels. Later in development, a similar pattern is apparent for labels that are phonotactically legal but differ in probability. Preschool-aged children displayed superior learning of object and action labels with high phonotactic probability rather than low probability (e.g., Storkel, 2001, 2003).

The findings from label-learning tasks are consistent with substantial evidence that children and adults display a processing advantage for high phonotactic probability sequences. In nonword repetition tasks, repetition is faster and more accurate for items with frequent phonemes and phoneme combinations than for rare phonemes and combinations (Coady & Aslin, 2004; Edwards, Beckman, & Munson, 2004; Gathercole, 1995; Vitevitch & Luce, 1998, 2005; Zamuner, Gerken, & Hammond, 2004). One interpretation of nonword repetition performance is that acoustic and articulatory processing is facilitated by practice with frequent sounds and sound sequences. The facilitation extends to unfamiliar phoneme combinations such as those that occur in nonwords. The processing advantage may also extend to words with frequent stress patterns. Vitevitch, Luce, Charles-Luce, and Kemmerer (1997) found that adults repeated bisyllabic trochaic nonwords faster than iambic nonwords regardless of phonotactic probability.

Integrating prosody and phonotactics in word learning

From this review, it is apparent that infants learn about prosodic and phonotactic regularities early in development and that these influence speech processing into adulthood. The current research investigated how infants use early knowledge of prosodic and phonotactic patterns in a fundamental linguistic process, linking the sounds of words with meanings. We addressed several key open questions concerning how early phonological development affects lexical development. First, young infants show a trochaic listening preference and a trochaic word segmentation strategy, but is there also a trochaic word-learning bias? Experience with noun stress patterns may lead infants to learn object labels that follow the highly familiar trochaic pattern more readily than labels that follow the less frequent iambic pattern. Second, young infants prefer to listen to high phonotactic probability words rather than low probability words, but is there any difference in how readily infants associate them with meanings? Infants' ability to discriminate sound sequences does not necessarily indicate that they treat them as functionally distinct (e.g., Stager & Werker, 1997). However, infants do differentiate between phonotactically legal and illegal object labels (Graf Estes et al., 2011; MacKenzie et al., 2012) and may also differentiate between high and low phonotactic probability labels. Finally, how do prosodic and phonotactic regularities interact in word learning? Word segmentation studies show that stress can outweigh other word boundary cues (e.g., Johnson & Jusczyk, 2001; Mattys et al., 1999), but it is not clear whether the dominance of prosodic patterns carries over into label learning.

In the current experiment, we investigated how prosody and phonotactics affect infants' learning of new object labels as well as how the features interact. We used a version of the Switch Task (Werker et al., 1998), a measure that taps infants' ability to learn label–object associations in the absence of support from social cues (e.g., eye gaze) or linguistic context (e.g., explicit labeling phrases). We tested infants' learning of bisyllabic object labels produced with trochaic or iambic stress. The labels consisted of high versus low phonotactic probability sequences based on the frequencies with which each phoneme occurred at a given word position in English, the infants' native language. Although several previous studies have examined attention to phoneme co-occurrences (e.g., Jusczyk et al., 1994; Storkel, 2001; Vitevitch & Luce, 1998), we investigated phoneme frequency effects because there is evidence that young children are more sensitive to this manipulation of phonotactics than to phoneme co-occurrences (Coady & Aslin, 2004). We tested 19-month-olds to allow for a comparison with Graf Estes and colleagues' (2011) demonstration that infants of around the same age differentiate between phonotactically legal and illegal labels.

This experiment provides a link between studies of what infants learn about native language sound patterns during the first year of life and how they apply this knowledge in word learning during the second year. In addition, this study presents a much-needed test of the contribution of statistical learning to early language development. Our predictions come from a statistical learning account of language acquisition, which proposes that infants learn about the structure of their native language by tracking patterns that are present in the input. A critique of statistical learning research has been that the controlled artificial speech streams that are commonly used in studies (e.g., Gómez, 2007; Johnson & Jusczyk, 2001; Saffran, Aslin, & Newport, 1996; Thiessen & Saffran, 2003) do not challenge learners in the same way in which natural languages do (Johnson & Tyler, 2010; see also Hay, Pelucchi, Graf Estes, & Saffran, 2011; Pelucchi, Hay, & Saffran, 2009). Ecologically valid tests of statistical learning are essential for establishing whether it has applications outside of the laboratory. In the current experiment, we relied on the information that infants had gathered from experience with the prosodic and phonotactic regularities of their native language rather than manipulate infants' experience with statistical regularities in an artificial language. If statistical learning is a viable contributor to natural language acquisition, there should be evidence that statistical regularities present in the ambient language shape learning.

Broadly, we hypothesized that sound sequences that are consistent with infants' experience with English would be easier to learn as labels than those that are not. Accordingly, we predicted that high phonotactic probability labels would be easier to learn than low probability labels. Alternatively, infants might only distinguish legal versus illegal phoneme combinations in new words (Graf Estes et al., 2011; MacKenzie et al., 2012) and might not make the more precise distinction between legal labels differing in probability. This experiment also addressed whether there is a trochaic bias for learning object labels. Consistent with English lexical stress patterns (Kelly & Bock, 1988), infants show a bias for iambic action labels (Curtin et al., 2012). We hypothesized that infants would show the parallel bias for trochaic object labels over iambic object labels. However, Floccia and colleagues (2011) did not find a trochaic bias for learning minimal pair object labels. If the trochaic bias also does not occur here, when labels differ by multiple phonemes and in the absence of social and linguistic labeling cues, it will strengthen the notion that trochaic stress does not promote label learning.

One of the novel contributions of the current experiment is that it investigated how knowledge of phonotactics and prosody interact in word learning. Combining these factors allowed us to examine whether one cue overrides the other as well as whether the influence of each cue depends on the other. We predicted a possible interaction of phonotactic probability and prosody such that infants might rely on support from both common linguistic patterns. That is, they may readily learn high probability trochaic labels but have difficulty in learning labels that are inconsistent with either the predominant stress or phonotactic patterns of their native language.

Method

Participants

The participants were 66 infants (26 girls and 40 boys) between 18.8 and 20.3 months of age (M = 19.4 months, SD = 0.37). English was the primary language spoken in the home for all infants. Based on a parental interview, we determined that 18 infants had exposure to a second language at home or in a child care setting; at least 75% of the infants' language exposure was to English (mean second language exposure = 12%). The pattern of results did not change when children hearing two languages were excluded from the analyses. All infants were born full term and had no history of chronic ear infections or hearing problems. Infants were randomly assigned to one of four label conditions in a 2 $\times$ 2 design examining phonotactic probability (high vs. low) and stress (trochaic vs. iambic): high probability trochaic (n = 16, M_{age} = 19.5 months), high probability iambic (n = 16, M_{age} = 19.3 months), low probability trochaic (n = 16, M_{age} = 19.5 months), and low probability iambic (n = 18, M_{age} = 19.3 months). An additional 24 infants were excluded from analyses because of fussiness or inattention (n = 22) or parental interference (n = 2). The experimenter judged an infant's fussiness, inattention, or parental interference immediately after data collection before looking at the data. If the experimenter was unsure about whether the infant should be excluded, a second naive experimenter reviewed the video.

Stimuli

Auditory stimuli

The test items were bisyllabic CV·CVC nonsense words (where "C" represents consonant and "V" represents vowel) designed by Coady and Aslin (2004) for use in a nonword repetition task. Based on pilot testing, we selected the items from Coady and Aslin's set (Experiment 1) that adult native English speakers judged to be the most and least plausible English words. The high probability words were moʊdaɪk (moe-dike) and daɪmus (die-moose), and the low probability words were geɪfaʊθ (gay-fouth) and fɔʃaʊtʃ (faw-shouch).

Based on a corpus analysis of child-directed speech, Coady and Aslin (2004; see also Coady & Aslin, 2003) created the high phonotactic probability nonwords by selecting the consonants that had the highest frequency of occurrence overall and the highest frequency of occurrence at a given syllable position (syllable-initial or syllable-final) in the corpus. They selected the consonants with the opposite pattern for the low probability nonwords. Coady and Aslin also selected the highest versus lowest frequency vowels. To avoid ambisyllabicity, in which a consonant acts as the offset of one syllable and the onset of the next syllable, all vowels were tense vowels (see Coady & Aslin, 2004, for design details). Using tense vowels, rather than the reduced vowels common to unstressed syllables, also allowed us to maintain segmentally identical trochaic and iambic labels.

To form nonwords differing in overall phoneme frequency, Coady and Aslin (2004, Experiment 1) assembled sequences of high frequency phonemes to form high phonotactic probability nonwords and low frequency phonemes to form low probability nonwords. We used overall phoneme frequency as our manipulation of phonotactic probability because Coady and Aslin's (2004) evidence indicated that for phonotactically legal sequences, children are sensitive to differences in overall phoneme frequency before phoneme combination frequency.

The auditory stimuli consisted of five tokens of each label produced in an infant-directed style, each separated by 800 ms of silence. The sequence of tokens was looped and repeated for the duration of the trial. Acoustic characteristics of the labels, analyzed in Praat (Boersma & Weenink, 2010), are shown in Table 1. Although perception of stress is affected by many factors, typically stressed syllables have higher intensity, have higher pitch (often indexed by fundamental frequency, F_0), and are longer in duration than unstressed syllables (e.g., Lehiste, 1970). In our labels, intensity and fundamental frequency provided the most consistent cues to word-initial stress, whereas duration and fundamental frequency provided the most consistent cues to word-final stress. Adult judgments ($n = 15$) of the labels indicated that adults could reliably identify the stressed syllables for all label types (93–97% correct, no significant differences across conditions).

Crossing the two dimensions of phonotactic probability with the two dimensions of stress yielded four conditions: (a) high probability trochaic labels (*DIE-moose* and *MOE-dike*), (b) high probability iambic labels (*die-MOOSE* and *moe-DIKE*), (c) low probability trochaic labels (*GAY-fouth* and *FAW-shouch*), and (d) low probability iambic labels (*gay-FOUTH* and *faw-SHOUCH*).

Visual stimuli

The two novel objects are shown in Fig. 1. Object 1 was displayed at 12 × 8 cm, and Object 2 was displayed at 10 × 10 cm. They were shown within a 27 × 20-cm white rectangle at the center of the screen. Each object bounced in an arc from left to right while repetitions of a spoken label played. The timing of the labeling was not linked to the object's movement.

Apparatus and procedure

Each infant sat on a parent's lap in a sound attenuated booth approximately 1 m away from a large television screen. To prevent bias, the parent listened to music over headphones and the experimenter was in a separate booth unable to see or hear the stimuli. A camera below the television screen was

Table 1
Acoustic characteristics of test items averaged across five tokens per label.

Labels		Syllable	Intensity (dB)	Duration (s)	F_0 (Hz)
High probability (moʊdaɪk, daɪmus)	Trochaic	1	79.0	.318	269
		2	71.8	.632	191
	Iambic	1	77.4	.285	202
		2	74.8	.854	243
Low probability (geɪfaʊθ, fɔʃaʊtʃ)	Trochaic	1	81.2	.287	295
		2	72.1	.850	205
	Iambic	1	76.9	.325	222
		2	76.2	.843	249

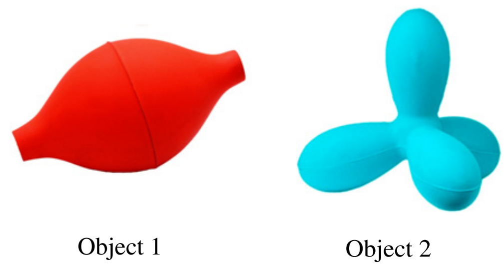

Fig. 1. Novel objects that received labels. Object 1 was labeled daɪmus (high phonotactic probability) or fɔʃaʊtʃ (low probability). Object 2 was labeled moʊdaɪk (high probability) or geɪfaʊθ (low probability). The same label occurred in trochaic and iambic conditions.

connected to a digital recording device that displayed a video feed of the infant's face to the experimenter and recorded the sessions for offline reliability coding. The experimenter indicated the infant's looking responses and controlled stimuli presentation using the program Habit X (Cohen, Atkinson, & Chaput, 2004). At the start of each trial, a cartoon appeared at the center of the screen. When the infant looked at it, the experimenter initiated a stimulus video by depressing a button on the computer keyboard. The video continued for as long as the infant looked, for up to 20 s. When the infant looked away for at least 1 s, the cartoon returned. If the infant looked for less than 2 s at a given trial, the trial was repeated. Habit X tallied the looking time on each trial.

Infants first participated in a familiarization trial that was intended to help them become accustomed to the audio and visual stimuli presentation before they participated in the label-learning task. In the trial, infants saw a computer-animated rotating gray screen and heard repetitions of the syllable nim (neem).

We used a version of the Switch Task (Werker et al., 1998) to assess learning of the object labels. During habituation trials, infants viewed two consistent label–object pairings shown one at a time (see Fig. 1). The label–object pairings continued in a pseudorandom order until the infant met the habituation criterion, namely, a looking time decrement of 50% across the last three trials compared with the first three trials. During testing, there were two types of test trials. In *same* test trials, the label–object pairings were consistent with habituation. In *switch* test trials, the objects swapped labels (i.e., Object 1 played with Label 2). The rationale behind the Switch Task is that if infants learn the label–object pairings during habituation, they will look longer during switch test trials than during same trials because switch trials violate the original pairings. The dependent measure is the looking time difference score, calculated as the duration of looking time to switch trials minus looking time

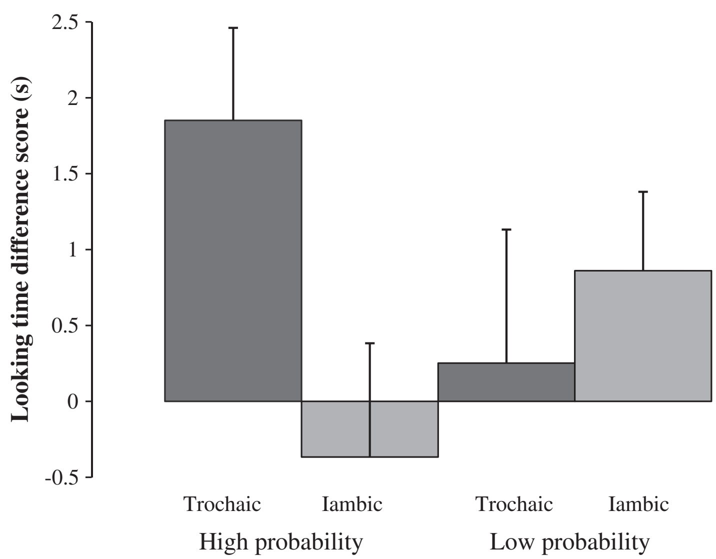

Fig. 2. Mean looking time difference scores for infants in each label condition. Looking time difference scores were calculated as looking time to switch test trials – looking time to same test trials. Error bars represent standard errors.

Table 2
Mean (and standard deviation) looking time on same and switch test trials, time to habituate, and number of trials to habituate for infants in each label condition.

Label condition	Same trial looking time (s)	Switch trial looking time (s)	Time to habituate (s)	Trials to habituate
High probability				
Trochaic	6.79 (3.1)	8.64 (3.3)	116.9 (63.2)	11.8 (5.9)
Iambic	6.24 (2.9)	5.87 (3.1)	92.4 (32.2)	9.3 (3.3)
Low probability				
Trochaic	5.70 (3.1)	5.96 (3.1)	100.3 (53.1)	11.6 (5.6)
Iambic	5.66 (3.0)	6.52 (2.8)	117.1 (84.5)	11.3 (6.1)

to same trials. Infants viewed four test trials of each type. They were randomly assigned to one of eight test orders that balanced the order of presentation of same and switch trials and prevented identical trials from being presented on successive trials. Because the stimuli presentation was infant-controlled, infants' responses were coded online. A second coder coded 26% of the participants ($n = 17$) offline from video recordings. The interobserver correlation for the duration of looking on each trial was high ($r = .96$). The original online data are reported here.

Results

Infants' mean looking time difference scores (looking time to switch trials – looking time to same trials) for each label condition are illustrated in Fig. 2, and looking times to same and switch test trials are reported in Table 2. We analyzed the difference scores in a 2 (Phonotactic Probability: high vs. low) $\times 2$ (Stress: trochaic vs. iambic) between-participants analysis of variance (ANOVA).[1] There were no main effects of phonotactic probability, $F < 1$, or stress, $F(1,62) = 1.34$, $p = .242$, $\eta_p^2 = .02$. There was a significant interaction of probability and stress, $F(1,62) = 4.14$, $p = .046$, $\eta_p^2 = .06$. To probe the interaction, we conducted a set of planned comparisons using independent samples t tests (all tests are two-tailed with alpha = .05). For the high probability labels, there was a significant difference between trochaic and iambic stress, $t(30) = 2.29$, $p = .029$, $d = 0.81$. For the low probability labels, there was no significant difference, $t(32) = -.613$, $p = .544$, $d = -0.21$.

We also tested whether infants in each condition showed a looking time difference score that was significantly different from zero, indicating significantly longer looking on switch test trials compared with same test trials. Infants presented with high probability trochaic labels showed a significant switch trial preference, $t(15) = 3.04$, $p = .008$, $d = 0.76$, indicating that they learned the label–object pairings and detected when they were altered. Infants presented with high probability iambic labels, $t(15) = -0.49$, $p = .633$, $d = -0.12$, low probability trochaic labels, $t(15) = 0.286$, $p = .779$, $d = 0.07$, and low probability iambic labels, $t(17) = 1.67$, $p = .113$, $d = 0.39$, did not show a significant difference. Thus, there is no indication that infants in these groups learned the labels.[2]

In our final analyses, we examined whether the differences in performance across conditions could be attributed to Fennell, Byers-Heinlein, and Werker (2007), Graf Estes, Evans, Alibali, and Saffran (2007) and Thiessen (2011)differences in the duration of label exposure during habituation given that stimuli presentation was infant-controlled. We performed a pair of 2 (Probability: high vs. low) $\times 2$ (Stress: trochaic vs. iambic) between-participants ANOVAs of time to habituate and trials to habituate. There were no significant main effects or interactions in either analysis (all ps > .20). Although the groups differed in label-learning performance, exposure to labels during habituation was similar

[1] The results of the analyses are the same when Trial Type (same vs. switch) is included as a within-participants factor rather than analyzing the looking time difference score.

[2] Many studies using the Switch Task present one switch and one same test trial (e.g., Curtin, 2009; Fennell, Byers-Heinlein, & Werker, 2007; Werker et al., 2002). We presented four trials of each type to establish a more stable measure of infants' performance on the two trial types (see also Graf Estes, Evans, Alibali, & Saffran, 2007; Thiessen, 2011). For comparison with previous reports, we analyzed infants' performance on the first two trials (one same and one switch trial). The pattern of results was unchanged. Infants presented with high probability trochaic labels showed a significant switch trial preference ($M = 5.37$, $SD = 8.37$), $t(15) = 2.57$, $p = .021$, $d = 0.64$, but infants in the other groups did not: high probability iambic ($M = -0.14$, $SD = 6.67$), low probability trochaic ($M = -1.69$, $SD = 6.57$), low probability iambic ($M = 0.23$, $SD = 5.39$), all ps > .30.

across groups, as shown in Table 2. Infants did not exhibit a preference for high probability or trochaic items when they occurred as object labels, in contrast to findings from listening preference tasks with younger infants (Jusczyk et al., 1993, 1994). In addition, there were no correlations between infants' time to habituate and looking time difference scores (all *ps* > .18), and there were no correlations between infants' trials to habituate and looking time difference scores for any of the conditions (all *ps* > .20). Thus, infants' performance on the test trials was not driven by the duration of their exposure to the labels during habituation.

Discussion

We found that 19-month-old infants learned high phonotactic probability object labels with trochaic stress but did not learn the same phoneme sequences when they were presented with iambic stress. Infants also failed to learn low phonotactic probability labels regardless of stress pattern. To learn object labels in this task, infants required support from phonological regularities in both dimensions—common phonemes and a common stress pattern. During the first year of life, English-learning infants develop preferences for trochaic and high probability sound sequences, demonstrating that they have learned something about these aspects of native language sound structure (e.g., Jusczyk, Cutler, & Redanz, 1993; Jusczyk et al., 1994). The current findings indicate that by the middle of the second year, knowledge of prosodic and phonotactic patterns affect how readily infants learn new words. Furthermore, this is the first demonstration of an interaction between prosodic and phonotactic influences on word learning. We first address the findings regarding prosody, followed by the findings regarding phonotactics and the interaction of the two features.

The results concerning prosody show that lexical stress is a salient aspect of new words, but it does not override the effects of phoneme patterns as it has done in some word segmentation tasks (Johnson & Jusczyk, 2001; Johnson & Seidl, 2009; Mattys et al., 1999; Thiessen & Saffran, 2003). If stress dominated, we would expect infants to learn trochaic labels regardless of phonotactic probability. Perhaps the trochaic bias is not as strong in object label learning as it is in word segmentation. Alternatively, lexical stress may be a dominant characteristic when infants use stress and phonotactic cues to segment words before or during the process of associating them with meanings. In this experiment, the labels were produced in isolation; it remains to be explored how phonotactics and prosody interact when word segmentation and label learning are integrated.

Several differences in experimental design may contribute to why we found an advantage for learning trochaic (high probability) labels, whereas Floccia and colleagues (2011) found no trochaic bias for detecting phonemic detail in minimal pair object labels. Because the experiments investigated different ways in which prosodic and phonemic information interacts, the labels varied in several important phonological characteristics (e.g., labels contrasted by a single phoneme or multiple phonemes, phonotactic manipulations). For example, if our labels had been minimal pairs, the effect of stress might not have appeared; infants' processing of minimal pairs can differ from processing of labels that are more phonetically distinct because learning minimal pairs requires close attention to phonemic detail as well as associating word forms with objects (e.g., Werker et al., 1998, 2002). In addition, Floccia and colleagues' (2011) task involved interactions between a child and an adult, and the labels were embedded in naturalistic naming events and in natural sentences. With support from the social and linguistic contexts, young children may learn iambic labels at rates similar to trochaic labels (at least when labels are differentiated by phonemes in their stressed syllables) because they rely less on facilitation from prior knowledge of native language sound patterns. The Switch Task used in the current experiment provides minimal social and linguistic support, potentially allowing for a stronger influence of word form characteristics. Furthermore, the participants in Floccia and colleagues' experiments were somewhat older (18.3–25.7 months) than our participants (18.8–20.3 months). More skilled word learners may easily acquire a wider range of words than less skilled learners and may require less support from characteristics such as common lexical stress patterns.

One possible interpretation of the current findings is that the infants encoded stressed syllables but not unstressed syllables. This does not seem to explain the current results. First, if infants encoded only stressed syllables, they should have successfully learned the high probability iambic labels as well as the high probability trochaic labels. All of the syllables in the high probability labels were created from high frequency phonemes. Thus, the stressed second syllables of the iambic labels should have been learnable given that previous experiments have shown that infants can learn monosyllabic labels of similar or greater complexity (as well as confusability) by 19 months of age (e.g., Rost & McMurray, 2009; Werker et al., 2002). Second, there is previous evidence that infants encode unstressed syllables in newly learned words. Curtin (2010) found that 14-month-olds detected when a stressed syllable in a novel object label changed word position. Curtin and colleagues' (2012) finding that infants differentiate between iambic and trochaic action labels also supports the idea that infants detect and store unstressed syllables. Therefore, it is likely that the entire word form affected learning in the current experiment.

Our finding that infants learned trochaic, but not iambic, high probability object labels is consistent with Curtin and colleagues' (2012) demonstration of an iambic bias for action labels. For both actions and objects, infants learn labels more readily when they follow the typical native language stress pattern for that word type. Young word learners have already detected which stress patterns are associated with word types, and they apply this information to constrain how they associate words with referents.

We found that the effect of phonotactic probability depended on lexical stress. Infants showed distinct learning patterns for high versus low phonotactic probability labels, but only when they were presented with the predominant English stress pattern. Our findings help to connect the developmental course of phonotactic effects on speech processing across a range of ages and tasks. Young infants prefer to listen to high probability words rather than low probability words (Jusczyk et al., 1994). Older infants successfully learn labels consisting of phonotactically legal sound sequences but not illegal sound sequences (Graf Estes et al., 2011; MacKenzie et al., 2012). The current experiment reveals that infants' word learning is also sensitive to the more precise distinction between sequences of high versus low frequency phonemes. Preschoolers show a similar pattern (Storkel, 2001, 2003). Furthermore, in nonword repetition tasks with preschoolers, older children, and adults, participants show superior processing of high probability sequences over low probability sequences (Coady & Aslin, 2004; Edwards et al., 2004; Gathercole, 1995; Vitevitch & Luce, 1998, 2005; Zamuner et al., 2004). Our results indicate that the high phonotactic probability processing advantage does not require a vocabulary of thousands of words. Rather, learning about native language phoneme patterns can be applied early in lexical development.

Infants' performance in the current experiment also contributes to understanding of infants' underlying lexical representations. It supports the notion that young learners store detailed representations of word forms. Some accounts of phonological development have proposed that infants and young children store holistic representations or "unanalyzed wholes" that lack precise phonetic detail (Walley, 1993, p. 293; see also Saffran & Graf Estes, 2006, for a review). However, Coady and Aslin's (2004) nonword repetition task revealed that 2.5-year-olds differentiated nonwords (including the test items we used here) that varied in phoneme frequency. Coady and Aslin proposed that children's performance indicates that their word form representations contain fine-grained phonetic detail, similar to adults' representations. If young learners stored holistic representations, they could not track individual phoneme occurrences and phoneme frequency could not affect nonword repetition. Based on the current findings, infants' representations of word forms must be precise in order for phonotactic probabilities to be detected and applied to language acquisition tasks such as word learning.

Future research will be necessary to pull apart the many dimensions of phonotactics, such as word position, phoneme combination frequency, consonants versus vowels, and word complexity, to explore how they influence lexical acquisition (see Coady & Aslin, 2004, Experiments 2 and 3; Edwards et al., 2004; Storkel, 2001). In the current experiment, the phoneme frequency manipulation of phonotactics carried throughout each label; the labels consisted of all high frequency phonemes or all low frequency phonemes. We selected this manipulation because overall phoneme frequency is a potentially strong manipulation of phonotactics that is well-suited to young learners (Coady & Aslin, 2004). Nazzi and Bertoncini (2009) used a different definition of phonotactic patterns and found that 20-month-olds did not differentiate between labels that varied in phonotactics. Nazzi and Bertoncini tested French infants' learning of monosyllabic labels that differed in the positions of labial and coronal consonants; in French words (and in many other languages), labials (e.g., /b/, /p/) frequently precede coronals (e.g., /d/, /t/) (MacNeilage, Davis, Kinney, & Matyear, 1999). Thus, the phonotactic pattern involved the co-occurrence of classes of consonants and their typical word positions. The divergence between our findings and those of Nazzi and Bertoncini (2009) may have occurred because young word learners are more sensitive to overall phoneme frequency differences than to phonotactic patterns based on word position, phoneme combinations, or nonadjacent relationships. Learning of phoneme co-occurrence probabilities that is sufficiently robust to affect label learning may require more language experience than learning patterns of individual phoneme frequencies at given word positions because co-occurrence patterns require storing and detecting even more highly detailed information. These possibilities remain to be explored.

Although we found that children learned high probability trochaic words more readily than low probability and iambic words, children clearly do learn native language words with iambic stress and low phonotactic probability. We propose that during acquisition infants form implicit expectations about the forms that words are likely to take—expectations that are based on the statistical regularities of characteristics such as lexical stress and phonotactics. Words that are inconsistent with the bulk of learners' linguistic experience may require additional support to acquire. However, in this experiment, infants did not provide themselves with extra time to learn difficult labels. There were no differences between groups in time or trials to habituate. Although infants must become sufficiently familiar with the audio–visual stimuli for attention to wane during habituation, this decline in attention does not ensure that learning is thorough enough for infants to detect mismatches in pairs of familiar objects and familiar labels. Measures that are more sensitive to learning than the Switch Task (e.g., Yoshida, Fennell, Swingley, & Werker, 2009) may show that infants can learn low probability or iambic labels, but we expect that learning of high probability object labels with trochaic stress will remain stronger. Similarly, infants may learn action labels with trochaic stress under some conditions, but not as readily as action labels with iambic stress. In addition, Storkel's (2003) findings with preschoolers suggest that the difference in learning high and low probability labels should extend to labels for actions as well as objects.

Our findings suggest that infants detect detailed patterns of phoneme frequencies and lexical stress patterns, and these regularities affect how infants associate sounds with meanings during word learning. The influence of phonotactics and prosody did not require laboratory-based exposure, strengthening the claim that statistical learning can function outside of the laboratory as learners are faced with natural, imperfect, and highly complex input. Statistical learning experiments have frequently used artificial languages to model how infants learn natural languages because they allow manipulation of the cues that are available in the input (but see Hay et al., 2011; Pelucchi et al., 2009). A serious critique concerning statistical learning accounts is that the patterns presented in artificial languages are too simple and straightforward (e.g., Johnson & Tyler, 2010). Statistical regularities in natural languages are not fully reliable and occur amid other, potentially conflicting, cues to structure. Thus, investigations that tap infants' use of naturally occurring statistical regularities, such as the current experiment, form a valuable complement to artificial language experiments. They demonstrate the potential for statistical learning to contribute to natural language acquisition.

In conclusion, this research presents a means of connecting how infants' early learning about sounds contributes to the process of associating sounds with meanings during word learning. Infants readily learned object labels supported by their prior knowledge of native language phonotactic and prosodic patterns. They failed to learn object labels that did not provide support on both dimensions, consisting of uncommon phonemes and stress patterns. New words that are consistent with the phonotactic and prosodic regularities that infants have spent months gathering may be easier to associate with referents because they are built from robust phonological representations (see Beckman & Edwards, 2000; Edwards et al., 2004; Werker & Curtin, 2005). Infants have practice in perceiving, segmenting, and recognizing these sounds, so they can be accessed in new lexical items more effectively and flexibly than sound sequences that do not possess this basis in prior learning. Our findings reveal one way in which statistical learning about native language sound structure lays a foundation for lexical development.

Acknowledgments

This research was supported by grants to K.G.E. from the National Science Foundation (BCS0847379) and from the National Institute of Child Health and Human Development

(HD062755). We would like to thank Carolina Bastos, Stephanie Chen-Wu Gluck, and the members of the Language Learning Lab at the University of California, Davis for their assistance with this research. We would also like to thank Jessica Hay, Casey Lew-Williams, and Alexa Romberg for their comments on an earlier draft of this manuscript. We also thank the parents who generously contributed their time.

References

Beckman, M. E., & Edwards, J. (2000). The ontogeny of phonological categories and the primacy of lexical learning in linguistic development. *Child Development, 71*, 240–249.
Boersma, P., & Weenink, D. (2010). *Praat: Doing phonetics by computer* (Version 5.2.1) [computer program]. Retrieved from <http://www.praat.org>.
Coady, J. A., & Aslin, R. N. (2003). Phonological neighbourhoods in the developing lexicon. *Journal of Child Language, 30*, 441–469.
Coady, J. A., & Aslin, R. N. (2004). Young children's sensitivity to probabilistic phonotactics in the developing lexicon. *Journal of Experimental Child Psychology, 89*, 183–213.
Cohen, L. B., Atkinson, D. J., & Chaput, H. J. (2004). *Habit X: A new program for obtaining and organizing data in infant perception and cognition studies (Version 1.0) [computer program]*. Austin: University of Texas.
Curtin, S. (2009). Twelve-month-olds learn novel word–object pairings differing only in stress pattern. *Journal of Child Language, 36*, 1157–1165.
Curtin, S. (2010). Young infants encode lexical stress in newly encountered words. *Journal of Experimental Child Psychology, 105*, 376–385.
Curtin, S., Campbell, J., & Hufnagle, D. (2012). Mapping novel labels to actions: How the rhythm of words guides infants' learning. *Journal of Experimental Child Psychology, 112*, 127–140.
Curtin, S., Mintz, T. H., & Christiansen, M. H. (2005). Stress changes the representational landscape: Evidence from word segmentation. *Cognition, 96*, 233–262.
Cutler, A., & Norris, D. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 113–121.
Cutler, A. (2008). Lexical stress. In D. B. Pisoni & R. E. Remez (Eds.), *The handbook of speech perception* (pp. 264–289). Malden, MA: Blackwell.
Echols, C. H., Crowhurst, M. J., & Childers, J. B. (1997). The perception of rhythmic units in speech by infants and adults. *Journal of Memory and Language, 36*, 202–225.
Edwards, J., Beckman, M. E., & Munson, B. (2004). The interaction between vocabulary size and phonotactic probability effects on children's production accuracy and fluency in nonword repetition. *Journal of Speech, Language, and Hearing Research, 47*, 421–436.
Fennell, C. T., Byers-Heinlein, K., & Werker, J. F. (2007). Using speech sounds to guide word learning: The case of bilingual infants. *Child Development, 78*, 1510–1525.
Floccia, C., Nazzi, T., Austin, K., Arreckx, F., & Goslin, J. (2011). Lexical stress and phonetic processing in word learning in 20- to 24-month-old English-learning children. *Developmental Science, 14*, 602–613.
Friederici, A. D., & Wessels, J. M. (1993). Phonotactic knowledge of word boundaries and its use in infant speech perception. *Perception and Psychophysics, 54*, 287–295.
Gathercole, S. E. (1995). Is nonword repetition a test of phonological memory or long-term knowledge? It all depends on the nonwords. *Memory and Cognition, 23*, 83–94.
Gómez, R. L. (2007). Statistical learning in infant language development. In M. Gareth Gaskell (Ed.), *The Oxford handbook of psycholinguistics* (pp. 601–616). Oxford, UK: Oxford University Press.
Graf Estes, K., Edwards, J., & Saffran, J. R. (2011). Phonotactic constraints on infant word learning. *Infancy, 16*, 180–197.
Graf Estes, K., Evans, J. L., Alibali, M. W., & Saffran, J. R. (2007). Can infants map meaning to newly segmented words? Statistical segmentation and word learning. *Psychological Science, 18*, 254–260.
Hay, J., Pelucchi, B., Graf Estes, K., & Saffran, J. R. (2011). Linking sounds to meanings: Infant statistical learning in a natural language. *Cognitive Psychology, 63*, 93–106.
Johnson, E. K., & Jusczyk, P. W. (2001). Word segmentation by 8-month-olds: When speech cues count more than statistics. *Journal of Memory and Language, 44*, 548–567.
Johnson, E. K., & Seidl, A. H. (2009). At 11 months, prosody still outranks statistics. *Developmental Science, 12*, 131–141.
Johnson, E. K., & Tyler, M. D. (2010). Testing the limits of statistical learning for word segmentation. *Developmental Science, 13*, 339–345.
Jusczyk, P. W., Cutler, A., & Redanz, N. J. (1993). Infants' preference for the predominant stress patterns of English words. *Child Development, 64*, 675–687.
Jusczyk, P. W., Friederici, A. D., Wessels, J. M., Svenkerud, V. Y., & Jusczyk, A. M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language, 32*, 402–420.
Jusczyk, P. W., Houston, D. M., & Newsome, M. (1999). The beginnings of word segmentation in English-learning infants. *Cognitive Psychology, 39*, 159–207.
Jusczyk, P. W., Luce, P. A., & Charles-Luce, J. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language, 33*, 630–645.
Jusczyk, P. W., & Thompson, E. (1978). Perception of a phonetic contrast in multisyllabic utterances by 2-month-old infants. *Perception and Psychophysics, 23*, 105–109.
Kelly, M. H., & Bock, J. K. (1988). Stress in time. *Journal of Experimental Psychology: Human Perception and Performance, 14*, 389–403.
Lehiste, I. (1970). *Suprasegmentals*. Cambridge, MA: MIT Press.

MacKenzie, H., Curtin, S., & Graham, S. A. (2012). 12-month-olds' phonotactic knowledge guides their word–object mappings. *Child Development, 83*, 1129–1136.
MacNeilage, P. F., Davis, B. L., Kinney, A., & Matyear, C. L. (1999). Origin of serial output complexity in speech. *Psychological Science, 10*, 459–460.
Mattys, S. L., & Jusczyk, P. W. (2001). Phonotactic cues for segmentation of fluent speech by infants. *Cognition, 78*, 91–121.
Mattys, S. L., Jusczyk, P. W., Luce, P. A., & Morgan, J. L. (1999). Phonotactic and prosodic effects on word segmentation in infants. *Cognitive Psychology, 38*, 465–494.
McQueen, J. M. (1998). Segmentation of continuous speech using phonotactics. *Journal of Memory and Language, 39*, 21–46.
McQueen, J. M., Norris, D., & Cutler, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 621–638.
Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29*, 143–178.
Morgan, J. L. (1996). A rythmic bias in preverbal speech segmentation. *Journal of Memory and Language, 35*, 666–688.
Nazzi, T., & Bertoncini, J. (2009). Phonetic specificity in early lexical acquisition: New evidence from consonants in coda positions. *Language and Speech, 52*, 463–480.
Nazzi, T., Bertoncini, J., & Mehler, J. (1998). Language discrimination by newborns: Toward an understanding of the role of rhythm. *Journal of Experimental Psychology: Human Perception and Performance, 24*, 756–766.
Pelucchi, B., Hay, J. F., & Saffran, J. R. (2009). Statistical learning in a natural language by 8-month-old infants. *Child Development, 80*, 674–685.
Peperkamp, S., Vendelin, I., & Dupoux, E. (2010). Perception of predictable stress: A cross-linguistic investigation. *Journal of Phonetics, 38*, 422–430.
Rost, G. C., & McMurray, B. (2009). Speaker variability augments phonological processing in early word learning. *Developmental Science, 12*, 339–349.
Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science, 274*, 1926–1928.
Saffran, J. R., Werker, J. F., & Werner, L. A. (2006). The infant's auditory world: Hearing, speech, and the beginnings of language. In: W. Damon & R. M. Lerner (Series Eds.) & R. Siegler & D. Kuhn (Vol. Eds.), *Handbook of child psychology*, *Vol. 2*. *Cognition, perception, and language* (pp. 2058–2108). Hoboken, NJ: John Wiley.
Saffran, J. R., & Graf Estes, K. M. (2006). Mapping sound to meaning: Connections between learning about sounds and learning about words. In R. Kail (Ed.). *Advances in child development and behavior* (Vol. 34, pp. 1–38). New York: Elsevier.
Sansavini, A., Bertoncini, J., & Giovanelli, G. (1997). Newborns discriminate the rhythm of multisyllabic stressed words. *Developmental Psychology, 33*, 3–11.
Shukla, M., Nespor, M., & Mehler, J. (2007). An interaction between prosody and statistics in the segmentation of fluent speech. *Cognitive Psychology, 54*, 1–32.
Stager, C. L., & Werker, J. F. (1997). Infants listen for more phonetic detail in speech perception than in word-learning tasks. *Nature, 388*, 381–382.
Storkel, H. L. (2001). Learning new words: Phonotactic probability in language development. *Journal of Speech, Language, and Hearing Research, 44*, 1321–1337.
Storkel, H. L. (2003). Learning new words. II. Phonotactic probability in verb learning. *Journal of Speech, Language, and Hearing Research, 46*, 1312–1323.
Thiessen, E. D. (2011). When variability matters more than meaning: The effect of lexical forms on use of phonemic contrasts. *Developmental Psychology, 47*, 1448–1458.
Thiessen, E. D., & Saffran, J. R. (2003). When cues collide: Use of stress and statistical cues to word boundaries by 7- to 9-month-old infants. *Developmental Psychology, 39*, 706–716.
Vitevitch, M. S., & Luce, P. A. (1998). When words compete: Levels of processing in perception of spoken words. *Psychological Science, 9*, 325–329.
Vitevitch, M. S., & Luce, P. A. (2004). A web-based interface to calculate phonotactic probability for words and nonwords in English. *Behavior Research Methods, Instruments, and Computers, 36*, 481–487.
Vitevitch, M. S., & Luce, P. A. (2005). Increases in phonotactic probability facilitate spoken nonword repetition. *Journal of Memory and Language, 52*, 193–204.
Vitevitch, M. S., Luce, P. A., Charles-Luce, J., & Kemmerer, D. (1997). Phonotactics and syallable stress: Implications for the processing of spoken nonsense words. *Language and Speech, 40*, 47–62.
Walley, A. C. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review, 13*, 286–350.
Waxman, S. R., & Lidz, J. L. (2006). Early word learning. In: W. Damon & R. M. Lerner (Series Eds.) & R. Siegler & D. Kuhn (Vol. Eds.), *Handbook of child psychology*, *Vol. 2*. *Cognition, perception, and language* (pp. 299–335). Hoboken, NJ: John Wiley.
Weber, A., & Cutler, A. (2006). First-language phonotactics in second-language listening. *Journal of the Acoustical Society of America, 119*, 597–607.
Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word–object associations by 14-month-old infants. *Developmental Psychology, 34*, 1289–1309.
Werker, J. F., & Curtin, S. (2005). PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development, 1*, 197–234.
Werker, J. F., Fennell, C. T., Corcoran, K. M., & Stager, C. L. (2002). Infants' ability to learn phonetically similar words: Effects of age and vocabulary size. *Infancy, 3*, 1–30.
Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7*, 49–63.
Yoshida, K., Fennell, C., Swingley, D., & Werker, J. F. (2009). 14-month-olds learn similar-sounding words. *Developmental Science, 12*, 412–418.
Zamuner, T. S., Gerken, L., & Hammond, M. (2004). Phonotactic probabilities in young children's speech production. *Journal of Child Language, 31*, 515–536.