Published in final edited form as:

Lang Cogn Neurosci. 2014 December 1; 29(4): 1311–1316. doi:10.1080/23273798.2014.912342.

The influence of known-word-frequency on the acquisition of new neighbors in adults: evidence for exemplar representations in word-learning

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Abstract

Previous studies showed that a new word that is similar to many known words will be learned better than a new word that is similar to few known words (Storkel et al., 2006). In the present study we created novel words that were phonological neighbors to lexical hermits—or known words that do not have any phonological neighbors—that varied in frequency of occurrence. After several exposures, participants learned a higher proportion of novel words that were neighbors of high frequency known-words than nonwords that were neighbors of low frequency known-words. The present results have implications for abstractionist versus exemplar models of the mental lexicon and language processing, as well as for accounts of word frequency in models of language processing.

Keywords

word learning; word frequency; neighborhood density; hermits

It is widely accepted that several phonological word-forms are activated and interact with each other in the lexicon during spoken word recognition and during spoken word production (Gaskell & Marslen-Wilson, 1997; Luce & Pisoni, 1998; Marslen-Wilson, 1987; McClelland & Elman, 1986; Norris, 1994; Peramunage et al., 2011; Vitevitch, 2002; Vitevitch, Ercal & Adagarla, 2011). Increasing amounts of evidence indicate that phonological word-forms stored in the lexicon are also activated during the acquisition of new words and influence language processing in various ways (e.g., Storkel, Armbruster, and Hogan, 2006). For example, Gaskell and Dumay (2003) had adults learn novel words that overlapped a great deal with known words in the lexicon (e.g., *cathedruke* derived from *cathedral*). Immediately after exposure to the novel words, facilitation in processing of the known word, *cathedral*, was observed (in Experiment 1). However, after 1 week had passed

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(without additional exposures; Experiment 3) they observed effects of competition on the known words from the newly learned words. The results of these experiments show that new words influence the recognition of previously known words.

In addition to newly learned words influencing the processing of previously known words, work by Storkel et al. (2006) suggests that characteristics of known words can influence how easily a new word is learned. Storkel et al. had adults learn novel words that were either similar to few known words (i.e., the new words had a sparse phonological neighborhood) or to many known words (i.e., the new words had a dense phonological neighborhood). At the end of training, Storkel et al. found that participants learned a higher proportion of novel nonwords that were similar to many known words (i.e., they had dense phonological neighborhoods) than novel nonwords that were similar to few known words (i.e., they had sparse phonological neighborhoods). Whereas Gaskell and Dumay (2003) found that newly learned words influence how known words are processed, Storkel et al. (2006) found that the number of known words that resemble a new word influences the acquisition of a new word.

In the work of Gaskell and Dumay (2003), Storkel et al. (2006; Vitevitch & Storkel, 2013) and many others there is an assumption—at least implicitly—that the phonological representations that are known and acquired are abstract, stripped of indexical information and other types of acoustic-phonetic variability. However, there is an increasing amount of evidence that suggests the lexicon may contain not only abstract word-forms, but also exemplar representations of words (e.g., Goldinger, 1998; Johnson, 1997; McLennan & Luce, 2005; Vitevitch & Donoso, 2011; Vitevitch et al., 2013). (The idea of acoustic-phonetic exemplars in the lexicon should not be confused with the idea of experiencing multiple and variable examples of an object with the same name as examined in Perry et al., 2010.) If such exemplar representations of words exist in the lexicon, how do these exemplars influence the process of learning a new word?

From the exemplar perspective, a word that occurs often in the language will have many exemplars of that word stored in the lexicon, whereas a word that occurs less often in the language will have fewer exemplars of that word stored in the lexicon. With that in mind, consider the word-learning model proposed by Storkel et al. (2006) to account for the influence on acquisition of the number of known words that are neighbors with a novel word. If the number of exemplar representations of a known-word influences word-learning in the same way that the number of abstract representations of known phonological neighbors influences word-learning, then a high frequency word—which has more exemplars to resonant with than a low frequency word—would have an advantage in "attracting" a novel neighbor to the lexicon.

To test this prediction about the number of exemplars of a known-word (as a function of word frequency) influencing the acquisition of a phonological neighbor of that known word we identified words in the lexicon that had no phonological neighbors—so called lexical hermits (Vitevitch, 2008)—but which varied in their frequency of occurrence in the language. We then created novel words that were phonological neighbors of these high and low frequency known words. For example, participants were asked to learn the novel word /

depaim/, which is a phonological neighbor of the low frequency hermit *daytime*, and the novel word /dɑkpɚ/, which is a phonological neighbor of the high frequency hermit *doctor*.

We used the methodology employed in Storkel et al. (2006) to examine over multiple exposures how the frequency of occurrence of a known word might influence the acquisition of a novel neighbor. Again, we predicted that novel words that were phonological neighbors of known words with high frequency would be better learned than novel words that were phonological neighbors of known words with low frequency. Importantly, participants received equal exposure to both types of novel words; it was the frequency of occurrence of the known neighbor of the novel word that varied.

Method

Participants

Twenty-eight participants, enrolled in lower level psychology courses at the University of Kansas, took part in the experiment for credit towards a course requirement. None of the participants reported speech or hearing problems or uncorrected-visual disorders.

Stimuli

The stimuli consisted of 10 bisyllabic nonwords that were 5 phonemes long and phonotactically legal in English. We changed a single phoneme in 10 real English words that were lexical hermits (Vitevitch, 2008)—that is, they did not have any real English words as phonological neighbors (based on the substitution, addition, or deletion of a single phoneme; see Luce & Pisoni, 1998; Vitevitch, 2008; Vitevitch & Luce, 2004)—to form the nonwords. Based on Kučera and Francis (1967), five of the real word hermits are used often in the language (*mean* = 433.69 occurrences per million; *SD* = 242.04), and the remaining five hermit words are used rarely in the language (*mean* = 17.75 occurrences per million; *SD* =16.42; t (8) = 3.83, $p < .01$). There was no difference in the Age-of-Acquisition (AoA; Kuperman, Stadthagen-Gonzalez & Brysbaert, 2012) of the frequent words (*mean* = 4.31 rated AoA; *SD* =.77) and the infrequent words (*mean* = 4.64 rated AoA; *SD* =.79; t (8) = .67, p = .52). There was no difference in phonotactic probability of the frequent words and the infrequent words either. The mean *sum of the phones* for the frequent hermits = .2205 (*sd* = .06), and for the infrequent hermits = .2044 (*sd* = .03), t (8) = .52, p = .61. The mean s*um of the biphones* for the frequent hermits = .0105 (*sd* = .005), and for the infrequent hermits = .0112 (*sd* = .006); t (8) = .19, p = .85; Vitevitch & Luce, 2004).

Finally, there was no difference in the phonotactic probability of the novel words that were neighbors of the hermits. The novel neighbor of the frequent hermits had a mean *sum of the phones* = .1973 (*sd* = .04), and the novel neighbor of the infrequent hermits had a mean = .1903 (*sd* = .03), t (8) = .30, p = .77. The novel neighbor of frequent hermits had a mean *sum of the biphones* = .0088 (*sd* = .003), and the novel neighbor of the infrequent hermits had a mean = .0094 (*sd* = .004), t (8) = .26, p = .80; Vitevitch & Luce, 2004).

There was also no difference in the neighborhood density of the novel words that were neighbors of the hermits. The novel neighbor of the frequent hermits had a mean *number of* *neighbors* = 1 (*sd* = 0), and the novel neighbor of the infrequent hermits had a mean *number of neighbors* = 1 (*sd* = 0; Storkel & Hoover, 2010).

Each nonword was randomly paired with a picture of a nonsense-object (henceforth referred to as a nonobject) to act as a referent. The nonobjects were selected from Kroll and Potter (1984). There were no statistically significant differences between the pictures assigned to the nonwords derived from the frequent and infrequent words on concreteness ratings (the degree to which the nonobject resembles an object in the real world; as assessed in Kroll & Potter, 1984), first word associate strength, second word associate strength, and semantic set size (as assessed in Storkel & Adlof, 2009). For concreteness ratings there was no significant difference between the frequent words (*mean* = 4.56; *SD* =.77) and the infrequent words (*mean* = 3.94; *SD* =.82; t (8) = 1.23, p = .25). First word associative strength was determined in Storkel and Adlof (2009) by presenting the nonobject to a large group of participants and eliciting the first meaningfully-related word that came to mind. The total of the most frequent word given by participants was divided by the total number of participants. The frequent words (*mean* = .11; *SD* =.04) did not differ significantly from the infrequent words (*mean* = .20; *SD* =.09; t (8) = 1.96, p = .09). Second word associative strength was determined in the same fashion as first word associative strength, except the second-most-frequent response was divided by the total number of participants. The frequent words (*mean* = .08; *SD* =.03) did not differ significantly from the infrequent words (*mean* = .10; *SD* =.02; t (8) = 1.37, p = .21). Semantic set size refers to the number of semantic neighbors given as responses to the items in Storkel and Adlof (2009). The frequent words (*mean* = 10.6 semantic neighbors; *SD* =.55) did not differ significantly from the infrequent words (*mean* = 10.20 semantic neighbors; *SD* =.45; t (8) = 1.26, p = .24).

A male native-speaker of American English (the first author) produced all of the nonwords by speaking at a normal rate and loudness level into a high-quality microphone in an Industrial Acoustics Company (IAC) sound-attenuated booth. The utterances were digitally recorded using a Marantz PMD671 recorder. The digital recording was then transferred directly to hard-drive so that each word could be edited into an individual sound file using the program Praat (Boersma & Weenink, 2009). Statistical analyses confirmed that there was no significant difference in duration between the nonwords derived from the frequent (*mean* = 722.2 *msec; SD* = 23.76) and infrequent hermits (*mean* = 731.4 *msec; SD* = 80.02; t (8) = .25, p = .81).

Procedure

The methodology in the current experiment was adapted from that used in Storkel et al. (2006) and Storkel and Lee (2011). Participants first took part in a baseline picture-naming task, in which they were shown each of the 10 pictures and asked to name each object. If they did not know the name of the object (either in the baseline test or in subsequent tests) participants were asked to say “Don’t Know.” Participants then saw each image of a nonobject on the computer screen while the associated nonword was presented auditorily over headphones. The nonwords appeared as the final word in the phrase, “This is a ____”. Training ended after all 10 nonword-nonobject pairs in the list were presented (in a different random order to each participant), and another picture-naming task was then administered (Test 1).

Participants then received another training block in which they saw each image of a nonobject on the computer screen while the associated nonword was presented auditorily over headphones. The nonwords appeared as the final word in a set of short phrases (e.g. “This is a ____”, “Look at the _____”, “Remember, it’s a _____”, “Listen closely, it’s called a _____”, “Don’t forget the ____”). Each phrase was presented only once, giving the participant 5 exposures to each nonword-nonobject pairing before the next nonword-nonobject pairing was presented. Training ended after all 10 nonword-nonobject pairs were presented. Nonword-nonobject pairs were presented in a different random order in each training block and for each participant. This training session was followed by another picture-naming task (Test 2).

Finally, participants received a final training block in which they saw each image of a nonobject on the computer screen while the associated nonword was presented auditorily over headphones in the same short phrases as above (presented in a different random order for each participant), for an additional 5 exposures. At the completion of this training block participants had received 11 exposures to the nonword-nonobject pairs, and a final picture-naming task was administered (Test 3).

Trials in the picture-naming task proceeded in the following way: ***** appeared for 1000ms to signal the start of a trial, followed by a nonobject appearing in the center of the screen. Participants were instructed to say out loud the nonword that was associated with the nonobject into a microphone, and to press a button on a response box to begin the next trial. The presentation of stimuli and collection of responses were all controlled by PsyScope (Cohen et al., 1993).

Results

A repeated-measures *ANOVA* was used to analyze the data. Test period (baseline, 1, 2, 3) and word frequency of the known word (frequent or infrequent) were the independent variables. Accuracy rate was the dependent variable of interest. As is common in experiments of word-learning, the reaction times in the picture-naming task in the present experiment were not analyzed because (1) the long response times raise doubts that an automatic retrieval process was assessed in this task [at Test 1, mean response time ~ 4s, at Test 2, mean response time ~3s, and at Test 3, mean response time ~2.5s, whereas in the picture-naming task used in Chan and Vitevitch (2010) with well-known English words the mean response time was approximately .7s.], and (2) the small proportion of accurate responses would yield an unreliable estimate of performance.

The responses of each participant were transcribed and marked as correct if three of the five phonemes in the nonword were produced correctly. This criterion is similar to that used in Storkel et al. (2006) and yields similar results as the stricter criterion of all five phonemes being correct (with the exception that performance for the strict criterion tends to be lower overall).[1] The results from the *ANOVA* showed a significant main effect for testing period, *F*

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(3, 81) = 86.26, $p < .0001$. Not surprising, performance at subsequent testing periods improved with additional training. Mean performance at each test period (Table 1) differed significantly from performance at the other test periods: Baseline (*mean* = 0), Test 1 (*mean* = .10), Test 2 (*mean* = .35), Test 3 (*mean* = .60), *Scheffe's test* all *p's* < .0001.

More interesting, we observed a significant main effect for frequency of occurrence of the known hermits, F (1, 27) = 44.23, $p < .0001$. A larger proportion of nonwords that were neighbors of frequent known words were learned (*mean* = .32; *SD* = .18) than were nonwords that were neighbors of infrequent known words (*mean* = .21; *SD* = .16; *Scheffe's test p* < .0001; *Cohen's d* = .65); this pattern was consistent across the three testing periods. Statistical conventions suggest that *Cohen's d* (Cohen, 1988) around .2 to .3 is considered a small effect, around .5 is considered a medium effect, and greater than .8 is considered a large effect. By these conventions, the effect observed in the present experiment is considered medium in magnitude.

A significant interaction between testing period and frequency of occurrence of the known hermits was also observed, F (3, 81) = 7.49, $p < .001$. This interaction, however, is an artifact of including the baseline performance (*mean* = 0 in both conditions) in the analysis. When baseline performance was excluded from the analysis this interaction was no longer significant, F (2, 54) = 1.11, $p = .34$. The low performance and lack of a difference between frequent and infrequent known words observed at baseline was expected, serving to verify that the nonobjects were indeed novel to the participants and that there were no unforeseen differences in the nonobjects that might give an advantage to one condition over the other. The difference between frequent and infrequent known words only emerged after participants received training where the labels for the nonobjects were introduced.

Discussion

Various language processes including word recognition, word production and word learning are often modeled with abstract representations of phonological word-forms in the mental lexicon. An increasing amount of evidence suggests that exemplar representations are also stored in the mental lexicon. In the present study we examined whether exemplar representations might play a role in the acquisition of novel words by having participants learn a new word that was a phonological neighbor of a high frequency known word or a phonological neighbor of a low frequency known word.

In the exemplar view of the mental lexicon, a frequent word will have many exemplars stored in the lexicon, whereas an infrequent word will have few exemplars stored in the lexicon. Given the previous results of Storkel et al. (2006), who found that the number of known words that a novel word is phonological neighbors with will affect how well that

[1]Of the responses that were "not correct," the most common "error" (~75%) was the response "Don't know." The next most common type of "error" (~20%) was to use one of the nonwords to name the wrong object (e.g., in Test 1 a participant might use the same novel name in response to three different objects, but by Test 3 the correct name-nonobject pairing had been established for the items). Another ~5% of the errors were responses in which participants would produce the initial phoneme of the nonword, but nothing else of the nonword (much like what happens in the tip-of-the-tongue state with real words). Participants very rarely ($\ll$1%) produced a response that involved the substitution, addition or deletion of a phoneme somewhere in the novel word. There were too few responses of this type to allow us to analyze such responses in any way to make meaningful generalizations or interpretations.

novel word is learned, we predicted that novel words that were neighbors of a frequent word would have more exemplars to “latch on” to in memory compared to novel words that were neighbors of an infrequent word, thereby affording a learning advantage to novel words that were neighbors of frequent words. The results of the present study were consistent with our prediction: novel words that were neighbors of a frequent word were learned more accurately than novel words that were neighbors of an infrequent word. Despite the simplicity of the present findings, the present results have significant implications for models of word learning as well as for accounts of word frequency in various models of language processing.

Word frequency effects are perhaps the most well-known and well-studied effects in psycholinguistics and related areas (e.g., Howes & Solomon, 1951). Models of various language processes have used a variety of approaches to represent differences in word-frequency including: differential resting activation levels of word-detectors, differential thresholds in word-detectors, the order in which the representations are searched, and having the frequency of occurrence of a word act as a bias at a later decision-stage in processing. Other alternatives suggest that word-frequency might be better represented in the connection between word-forms and semantic information (Baayen, 2010), as part of semantic information (e.g., Bates et al., 2003), or as the number of words that sound similar to a given word (see Footnote 5 in Vitevitch, Chan & Goldstein, 2014). What all of these approaches share is the (implicit) assumption that the frequency of occurrence of a word is encoded in an abstract representation of that word.

The present results suggest that word-frequency effects can alternatively be accounted for as differences in the number of exemplars stored in the lexicon. Furthermore, the present results show that the difference in the number of exemplars stored in the lexicon influences word-learning. This novel finding opens new avenues of exploration for how exemplar representations might influence the acquisition of novel words. Consider the hybrid model proposed by McLennan and Luce (2005), in which abstract representations are accessed rapidly, whereas exemplar representations are accessed more slowly. Given the difference in accessibility of abstract versus exemplar representations as a function of processing speed, one might be able to influence word-learning by manipulating the amount of time that learners have to process the novel words. For example, if the stimuli were presented more rapidly than they were presented in the present experiment abstract rather than exemplar representations would be favored, thereby resulting in an attenuation of the effects observed in the present experiment. Other manipulations commonly used to demonstrate the existence or influence of exemplar representations, such as varying the number of speakers or the affect of the speakers (Singh, 2008), may also be shown in future work to influence word-learning.

Although we believe that the present findings represent a significant challenge to widely accepted abstractionist approaches to representing word frequency in the lexicon, we briefly discuss an alternative hypothesis that is compatible with an abstractionist account (we thank an anonymous reviewer for proposing this intriguing hypothesis). The alternative account suggests participants in the present study experienced difficulty in retrieving the recently learned lexical representations in something akin to the tip-of-the-tongue (ToT) state. As shown in Vitevitch and Sommers (2003), older (but not younger) adults were more likely to experience ToT states for words with low- rather than high-neighborhood frequency; neighborhood frequency refers to the mean frequency of occurrence of the phonological neighbors of the word being retrieved. In the present study, the newly learned words that were neighbors of a known word with low frequency essentially have “low neighborhood frequency,” just like the words in Vitevitch and Sommers (2003), which could account for the poorer performance observed in the present study for the newly learned words that were neighbors of a known word with low frequency.

We grant that this account, which is consistent with abstractionist theories of speech production, is possible, but there are several factors that reduce the plausibility of it. First, no influence of neighborhood frequency was observed in younger adults (comparable in age to the participants in the present study) in the ToT elicitation task in Vitevitch and Sommers (2003), nor in the speech error elicitation task, known as the Spoonerisms of Laboratory Induced Predisposition (SLIP), used in Experiment 1 in Vitevitch (2002; however, see Vitevitch, 1997). Second, the novel words in the present experiment had been presented to participants in a training session just prior to each testing session. As Burke, MacKay, Worthley and Wade (1991) observed, recently activated items are less likely to be involved in ToT states compared to items that have not been used recently. Finally, the pattern of errors described in Footnote 1 raise additional doubt that a ToT-like state was solely responsible for the observed results.

Together these factors cast doubt on the plausibility of the abstractionist account, and increase our confidence in the novel hypothesis that we proposed: exemplar representations in the lexicon influence word learning. The existence of exemplar representations in the lexicon has important implications not only for word recognition (e.g., Goldinger, 1998), but also for word production, and as demonstrated in the present study, word learning. The implications of exemplar representations in the lexicon should also be explored in the context of language disorders and rehabilitation.

Acknowledgments

Funding

This work was supported by the National Institutes of Health-National Institute of Deafness and other Communication Disorders DC08095 and DC00052.

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Appendix. Nonword stimuli used in the experiment (and the real words from which they were derived)

High	Low
/bɹ ʌzɚ/ (brother)	/bIzev/ (behave)
/dɑkpɚ/ (doctor)	/depaim/ (daytime)
/fædḷi/ (family)	/frɜpḷ/ (freckle)
/nʌgIŋ/ (nothing)	/nepɨd/ (naked)
/tɨvait/ (tonight)	/toIdɨt/ (toilet)

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Table 1

Mean accuracy rates (and standard deviations) from the picture-naming task.

	Baseline	Test 1	Test 2	Test 3
Neighbor of frequent known-words	0.0 (0.0)	.16 (.17)	.45 (.27)	.68 (.29)
Neighbor of infrequent known-words	0.0 (0.0)	.04 (.08)	.26 (.24)	.53 (.32)