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Long-Term Knowledge Effects on Serial Recall of Nonwords Are Not Exclusively Lexical

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S. Roodenrys and M. Hinton (2002) reported superior recall for nonwords with large rather than small lexical neighborhoods when constituent biphone frequency was controlled, but comparable recall of high and low biphone frequency nonwords when neighborhood size was controlled, suggesting that long-term knowledge effects on nonword recall are lexically based. We report two experiments in which the same manipulations were made, but with neighborhood size controlled at the level of neighbor type. In Experiment 1, biphone frequency significantly influenced nonword recall when neighborhood size was controlled in this way. In Experiment 2, neighborhood size significantly influenced nonword recall when biphone frequency was controlled. These findings suggest that long-term knowledge contributions to nonword recall are not exclusively lexical but are based instead on both lexical and phonotactic knowledge of a language.

Keywords: short-term, redintegration, nonwords, phonotactics

In recent years there has been considerable interest in the mechanisms and processes supporting the immediate recall of nonwords, arising in part from the hypothesis that verbal short-term memory (STM) plays a crucial role in the acquisition of new word forms (Baddeley, Gathercole & Papagno, 1998). New word learning has been found to be facilitated by various levels of knowledge about a language (Storkel, 2001, 2004; Storkel & Rogers, 2000). Consistent with the proposed role of STM in the acquisition process, it is now clear that the familiarity of a novel phonological item also influences its memorability, with nonwords consisting of familiar phoneme combinations recalled more accurately than those constructed from less familiar combinations. The influence of familiarity on nonword recall has been demonstrated using both subjective measures, such as rated "wordlikeness" (Gathercole, 1995; Gathercole, Willis, Emslie & Baddeley, 1991), and measures based on the statistical frequency of particular phoneme combinations in a language (Gathercole, Frankish, Pickering & Peaker, 1999; Roodenrys & Hinton, 2002). Beneficial effects of familiarity on nonword recall have been attributed to the application of long-term knowledge to "clean up" partially degraded temporary memory traces in a redintegration process (Gathercole et al., 1999; Schweickert, 1993) or to the use of long-term knowledge to enhance the temporary storage of memory items (Gathercole & Martin, 1996; Gupta & MacWhinney, 1997).

There has recently been some debate concerning the exact source of familiarity effects in nonword serial recall. Nonword familiarity effects could arise through knowledge of the phonotactic regularities that characterize a language. Consistent with this view, Gathercole et al. (1999) reported superior recall accuracy for nonwords composed of phoneme pairs that occur frequently in English words than for those composed of infrequently occurring biphone pairs. More recently though, Roodenrys and Hinton (2002) have suggested that nonword recall accuracy is determined by knowledge of lexical items rather than phonotactic familiarity. The lexical properties of verbal stimuli are known to influence a number of language processing skills, such as phonological awareness (e.g., De Cara & Goswami, 2003) and word recognition skills (Vitevitch, 2002). Roodenrys and Hinton (2002) examined the impact that lexical neighborhood size had on immediate memory for nonwords. They reported superior recall for nonwords with large rather than small lexical neighborhoods when the two sets of stimuli were matched for mean biphone frequency but no significant difference in recall of high and low biphone frequency nonwords that were matched in terms of neighborhood size. On the basis of these findings, Roodenrys and Hinton (2002) proposed that familiarity effects in nonword recall are lexically rather than phonotactically based. They suggested that such effects are attributable to an influence on nonword recall accuracy from lexical representations rather than implicit phonotactic knowledge.

There is clearly some merit in the strategy used by Roodenrys and Hinton (2002) to assess the relative influences of biphone frequency and neighborhood size on nonword memorability. However, biphone frequency and neighborhood size are highly correlated (Vitevitch, Luce, Pisoni, & Auer, 1999), creating difficulties with this approach. Both Gathercole et al. (1999) and Roodenrys and Hinton (2002) assessed recall accuracy for consonant–vowel–consonant (CVC) nonwords, with the frequency of the constituent biphones assessed by counting the number of times each consonant–vowel (CV) and vowel–consonant (VC) biphone pair occurred in single-syllable words in the CELEX lexical database (Baayen, Piepenbrock, & van Rijn, 1993). Consider a substitution

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definition of a lexical neighbor (Luce, Pisoni & Goldinger, 1990), according to which a neighbor is any word that differs from a target item by the substitution of a single phoneme. By this definition, there are three types of neighbors for a CVC nonword: words that share the nonword's initial consonant and vowel (CV_ neighbors), words that share the nonword's vowel and final consonant (_VC neighbors) and words that share the nonword's initial and final consonants (C_C neighbors). When measurement of biphone frequency is based on single-syllable words, the numbers of CV_ and _VC neighbors of a CVC nonword will clearly be closely related to that nonword's CV and VC biphone frequency counts. The majority of the words used to determine the CV count are likely to be CV_ neighbors of the nonword, and the majority of the words used to determine the VC count are likely to be _VC neighbors. For example, the words *tide, wide, guide, ride,* and *bride* would be counted to obtain the frequency count for the VC biphone of the nonword *kide*. Of these words, all but *bride* are _VC neighbors of *kide*.

The close association between biphone frequency counts and CV_ and _VC neighbors leads to a systematic confound in the stimulus sets that Roodenrys and Hinton (2002) used in their experiments. Consider two sets of CVC nonwords with large or small neighborhood counts but comparable biphone frequency. If the frequencies of the constituent CV and VC biphones are controlled, and these measures are closely related to the numbers of CV_ or _VC neighbors, respectively, then the numbers of CV_ and _VC neighbors for nonwords in the two conditions will also be comparable. Thus, to achieve the neighborhood manipulation but match biphone frequency, the large lexical neighborhood nonwords must have more C_C neighbors than the small neighborhood nonwords. By the same reasoning, to create the two sets of nonwords for which neighborhood size is controlled and biphone frequency manipulated, the nonwords of low biphone frequency must have fewer CV_ and _VC neighbors than the nonwords of high biphone frequency. Therefore, to achieve a match on overall neighborhood size, the low-biphone frequency nonwords must have more C_C neighbors than the high-biphone frequency nonwords. This confound between biphone frequency and C_C neighbors means that beneficial effects of biphone frequency may have been masked in the Roodenrys and Hinton experiments by a lexical neighbor effect (mediated by C_C neighbors) operating in the opposite direction.

The following experiments were designed to determine whether the failure of Roodenrys and Hinton (2002) to find beneficial effects of biphone frequency in serial recall of nonwords resulted from a confound between biphone frequency and C_C neighborhood counts. The design of the two experiments involved identical manipulations to those made by Roodenrys and Hinton, but the total lexical neighborhood properties of the nonwords were additionally controlled at the level of lexical neighbor type.

Experiment 1

The first experiment manipulated biphone frequency while controlling for neighborhood size, using nonwords with a CVC structure. Neighborhood size was controlled at the level of lexical neighbor type such that the numbers of C_C, CV_ and _VC neighbors were comparable across the high- and low-biphone frequency conditions. The experimental procedure closely matched that of Roodenrys and Hinton (2002). If the effects of biphone frequency on serial recall accuracy are attributable exclusively to lexical knowledge, the results of this experiment should replicate Roodenrys and Hinton in finding no difference in recall accuracy for high- and low-biphone frequency nonwords.

Method

Participants. Twenty students from the University of Bristol took part in this experiment in compliance with a course requirement. All participants were native English speakers.

Materials. All the stimuli used were CVC nonwords and conformed to the phonotactic rules of the English language. Biphone frequency and neighborhood size counts were derived from the CELEX psycholinguistic database (Baayen et al., 1993) and were based on all of the words in CELEX that have a frequency of 1 or more. Biphone frequency counts were based on all words rather than restricting them to single-syllable words (cf. Roodenrys & Hinton, 2002) to provide a generalized measure of frequency of occurrence that would not be affected by idiosyncrasies in the occurrence of biphones in single-syllable words. The correlations between biphone frequency counts based on single-syllable words and those based on all words were significant (see below). Two sets of 40 nonwords were constructed so as to manipulate biphone frequency while controlling for lexical neighborhood size at the level of constituent neighbor type. The nonword sets were larger than those used by Roodenrys and Hinton to increase the number of observations made in each condition: The larger stimuli sets allowed a larger number of lists to be presented (16 as opposed to 10 lists), with more items presented per list (5 as opposed to 4 items). Two measures of biphone frequency were derived from the CELEX database: (a) the total number of times the constituent CV and VC pairs occur in all nonzero frequency words in the database (type count; cf. Roodenrys & Hinton, 2002) and (b) the number of times the constituent CV and VC pairs occur in all nonzero frequency words, weighting each word counted with respect to the log frequency of that word (token count). The token count provides a measure of frequency of occurrence adjusted for the fact that a biphone might occur in very few words but in words of particularly high frequency within a language. Summary biphone frequency information for stimuli in each condition is provided in Table 1. Note that across the two stimuli sets there were significant correlations between the frequency counts used here and those based on single-syllable words only (cf. Roodenrys & Hinton, 2002), for both the type measure, $r(122) = .36$, $p < .01$, and the token measure, $r(122) = .40$, $p < .01$. Neighborhood size was calculated as the number of nonzero-frequency CVC words in the CELEX database that differed from each nonword item by the substitution of a single phoneme. Summary neighborhood size information for stimuli in each condition is provided in Table 2. Constituent phoneme content was matched as closely as possible across conditions. Nonwords in the two conditions shared 93% of C_1 phonemes, 85% of V phonemes, and 93% of C_2 phonemes. Analysis by *t* tests demonstrated a significant difference in mean biphone frequency between stimuli in the high- and low-biphone frequency conditions, for both the type count $t(78) = 6.23$, $p < .01$, and the token count, $t(78) = 6.07$, $p < .01$, whereas neighborhood size did not differ between the two conditions: for CV_ neighbors, $t(78) = 1.55$, *ns*; for C_C neighbors, $t(78) = 0.47$, *ns*; and for _VC neighbors, $t(78) = 0.58$, *ns*. The stimuli, with International Phonetic Alphabet (IPA) transcriptions, are given in the Appendix.

The 40 nonwords in each condition were used to construct eight lists of five items such that in each list no C_1, V, or C_2 phoneme occurred more than once. A second set of eight lists was constructed by rearranging the items in different combinations according to the same criterion. To avoid item-specific serial position effects, the order of presentation of items within each list was rotated between participants such that Participant 1 was presented with items I_1, I_2, I_3, I_4, I_5; Participant 2 received the sequence I_2, I_3, I_4, I_5, I_1, and so forth. Participants were presented with the

Table 1
Biphone-Frequency Properties of the Stimuli Used in Experiments 1 and 2

Variable	Type count		Token count	
	C_1V	VC_2	C_1V	VC_2
Experiment 1				
High-biphone frequency	269.3 (114.8)	338.2 (272.4)	688.8 (322.0)	865.7 (695.5)
Low-biphone frequency	145.6 (58.5)	161.5 (74.5)	379.2 (153.1)	417.2 (203.1)
Experiment 2				
Large neighborhood	198.9 (75.9)	211.1 (88.8)	504.3 (196.1)	536.4 (220.1)
Small neighborhood	199.3 (79.5)	184.6 (102.7)	491.8 (199.3)	475.5 (274.1)

Note. Numbers in parentheses represent standard deviations. C_1 = initial consonant; V = vowel; C_2 = final consonant.

first block of both conditions before the second blocks were presented. The order of conditions was counterbalanced across participants. A set of three practice trials preceded the experiment. These consisted of CVC nonwords not used in the experimental stimuli sets.

Recordings of the spoken form of each nonword were made by a female native English speaker and stimuli lists were subsequently produced by sampling the single instance of each stimulus as required.

Procedure. Each participant was tested individually in a single session. Memory lists were presented through a computer via headphones at a rate of one item per second. Participants were instructed to begin spoken recall immediately following presentation of the final item and to recall items in strict serial order, indicating the location of any forgotten items by speaking "pass." The experimental session began with three practice lists. Recall responses were recorded onto the computer from a microphone attached to the headphones; these were subsequently scored as correct or incorrect phonemic responses by reference to the session recording.

Speech rate for the nonwords in each condition was measured after the recall trials. Participants repeated pairs of the nonwords 10 times as quickly as possible. Speech rates were recorded directly onto the computer from a microphone. The 40 nonwords in each condition were randomly paired for each participant, yielding 20 observations that were averaged and converted to items per second.

Results and Discussion

The mean proportion of items recalled correctly for the two conditions by trial block are shown in Table 3. A 2 × 2 repeated measures analysis of variance (ANOVA) was performed on the proportion of items correctly recalled as a function of list type (high or low biphone frequency) and trial block. This analysis established a significant main effect of list type, $F(1, 19) = 13.95$, $MSE = 0.009$, $p < .01$, with high-biphone-frequency nonwords being recalled more accurately than low-biphone-frequency nonwords. There was no effect of trial block, $F(1, 19) = 2.73$, $MSE = 0.004$, *ns*, and no interaction, $F(1, 19) = 0.32$, $MSE = 0.011$, *ns*.

The mean speech rate for the low-biphone-frequency items was 3.13 items per second, whereas the mean speech rate for the high-biphone-frequency items was 3.17 items per second. This difference was not significant on a paired *t* test, $t(19) = 1.03$, *ns*.

Although neighborhood size was statistically controlled in this experiment, the difference in neighborhood size was nonzero, and it thus remains plausible that differences in recall accuracy for the high- and low-biphone-frequency nonwords were mediated by small remaining differences in lexical neighborhood size. To establish whether this was the case, recall accuracy scores were calculated by item. The mean recall accuracy score for high-biphone-frequency nonwords was 16.0 ($SD = 5.7$), whereas the mean recall accuracy score for low-biphone-frequency nonwords was 12.8 ($SD = 4.9$). A repeated measures analysis of covariance was performed on these scores as a function of item type (high or low biphone frequency), with total lexical neighborhood size entered as a covariate. This analysis established a significant main effect of biphone frequency, $F(1, 77) = 6.57$, $MSE = 28.814$, $p < .05$, indicating that the recall advantage for high- over low-biphone-frequency nonwords was not attributable to any remaining differences in lexical neighborhood size in the controlled stimuli sets.

Overall, the results indicate that when neighborhood size is strictly controlled at the level of the constituent lexical neighbor types, biphone frequency does exert a significant beneficial influence on nonword serial recall accuracy. In Experiment 2 we

Table 2
Lexical Neighborhood Properties of the Stimuli Used in Experiments 1 and 2

Variable	CV_ Nsize	_VC Nsize	C_C Nsize	Total Nsize
Experiment 1				
High biphone frequency	8.1 (3.1)	7.2 (6.0)	5.3 (3.6)	20.5 (7.9)
Low biphone frequency	7.0 (3.1)	6.4 (5.3)	5.0 (3.5)	18.4 (7.2)
Experiment 2				
Large neighborhood	8.7 (3.4)	9.1 (4.9)	6.0 (4.3)	23.8 (5.6)
Small neighborhood	5.9 (2.8)	4.2 (3.0)	2.6 (2.0)	12.6 (3.4)

Note. Numbers in parentheses represent standard deviations. C = consonant; V = vowel; Nsize = neighborhood size.

Table 3
Mean Proportion of Items Correctly Recalled in Experiments 1 and 2

Condition	Block 1	Block 2
	Experiment 1	
Frequency		
High biphone	.38 (.04)	.42 (.05)
Low biphone	.31 (.04)	.33 (.03)
	Experiment 2	
Neighborhood		
Large	.41 (.03)	.40 (.03)
Small	.32 (.03)	.33 (.03)

Note. Numbers in parentheses represent standard errors of the mean.

manipulated lexical neighborhood size while controlling for biphone frequency.

Experiment 2

Method

Participants. Twenty adults took part in this experiment, none of whom had participated in Experiment 1. Participants were either students from the University of Bristol who took part in compliance with a course requirement or were volunteers who took part in the experiment in return for a small honorarium. All participants were native English speakers.

Materials. Two sets of 40 nonwords were constructed so as to manipulate lexical neighborhood size at the level of constituent neighbor type while controlling for biphone frequency. Summary information for stimuli in each condition is provided in Tables 1 and 2. Again, it should be noted that across the two stimuli sets there were significant correlations between the biphone frequency counts used here and counts based on single-syllable words only (cf. Roodenrys & Hinton, 2002), for both the type measure, $r(112) = .45, p < .01$, and the token measure, $r(112) = .49, p < .01$. Again an attempt was made to match constituent phoneme content as closely as possible across conditions. Nonwords in the two conditions shared 79% of C_1 phonemes, 86% of V phonemes, and 71% of C_2 phonemes. Analysis by *t* tests demonstrated a significant difference in neighborhood size between stimuli in the large and small neighborhood size conditions: for CV_ neighbors, $t(78) = 4.07, p < .01$; for C_C neighbors, $t(78) = 4.60, p < .01$; and for _VC neighbors, $t(78) = 5.34, p < .01$. Mean biphone frequency did not differ between the two conditions, on either the type count, $t(78) = 0.92$, *ns,* or the token count, $t(78) = 1.01$, *ns*.

The 40 nonwords in each condition were used to create eight lists of five items such that in each list no C_1, V, or C_2 phoneme occurred more than once. Apart from the selection of nonword items, the procedure was the same as for Experiment 1.

Results and Discussion

The mean proportion of items recalled correctly for the two conditions by trial block are shown in Table 2. A 2 × 2 repeated measures ANOVA was performed on the proportion of items correctly recalled as a function of list type (large or small neighborhood size) and trial block. This analysis established a significant main effect of list type, $F(1, 19) = 17.43$, $MSE = 0.008$, $p < .01$, with large-neighborhood-size nonwords being recalled more accurately than small-neighborhood-size nonwords. There was no effect of trial block, $F(1, 19) = .01$, $MSE = 0.006$, *ns,* and no interaction, $F(1, 19) = 1.07$, $MSE = 0.004$, *ns*.

The mean speech rate for the small neighborhood items was 2.81 items per second, whereas the mean speech rate for the large neighborhood items was 3.01 items per second. This difference was significant on a paired *t* test, $t(19) = 3.16, p < .01$. However, across the two conditions, speech rate and memory span were not significantly correlated with one another, $r(38) = .207$, *ns,* suggesting that differences in speech rate had little impact on recall performance in the two conditions. The relationship between speech rate and memory performance for the two conditions for each participant, averaged across blocks, is shown in Figure 1.

Although biphone frequency was statistically controlled in this experiment, the difference in biphone frequency for stimuli in the large and small neighborhood size conditions was nonzero. To establish whether or not the recall advantage for large- compared with small-lexical-neighborhood nonwords was mediated by small remaining differences in mean biphone frequency counts for stimuli in the two conditions, we calculated recall accuracy scores by item. The mean recall accuracy score for large-neighborhood nonwords was 16.3 ($SD = 6.2$), whereas the mean recall accuracy score for small-neighborhood nonwords was 12.9 ($SD = 5.7$). A repeated measures analysis of covariance was performed on these scores as a function of item type (large or small lexical neighborhood), with mean biphone frequency count entered as a covariate. With the type-based frequency count, this analysis established a significant main effect of neighborhood size, $F(1, 77) = 5.91$, $MSE = 35.383$, $p < .05$, reflecting superior recall of large- compared with small-lexical-neighborhood-size nonwords. The effect of lexical neighborhood size also remained significant with the token-based biphone frequency count in this analysis, $F(1, 77) = 5.99$, $MSE = 35.684$, $p < .05$. Therefore, these analyses indicate

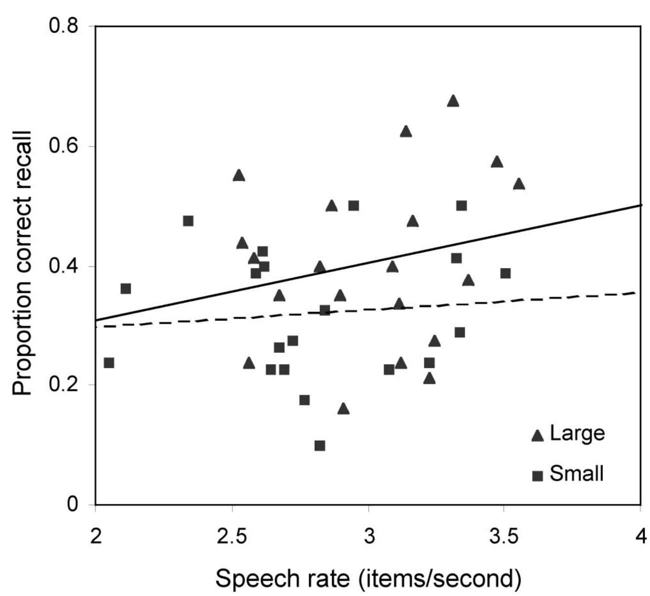

Figure 1. Recall performance as a function of speech rate for the large and small neighborhood size conditions in Experiment 2. Regression lines for the large and small neighborhood size conditions are indicated by full and dashed lines respectively.

that the recall advantage for large- over small-neighborhood-size nonwords was independent of small remaining differences in biphone frequency in the two stimuli sets. Overall, the results indicate a significant influence of lexical neighborhood size on nonword recall accuracy when constituent biphone frequency is controlled.

General Discussion

The experiments reported here demonstrate that nonword serial recall is influenced by both biphone frequency and lexical neighborhood size and that these effects are independent of each other. The influence of biphone frequency on nonword recall accuracy when neighborhood size is controlled at the level of constituent neighbor types suggests that the absence of a biphone frequency effect in the experiments reported by Roodenrys and Hinton (2002) was due to a confound with C_C neighbors; in the Roodenrys and Hinton study, nonwords in the low-biphone-frequency condition had larger numbers of C_C neighbors than nonwords in the high-biphone-frequency condition.

The implication of these results with regard to the nature of long-term knowledge contributions to nonword recall are clear. Beneficial effects of biphone frequency on nonword recall are not consistent with Roodenrys and Hinton's (2002) proposal that the contribution of long-term knowledge to nonword recall is due exclusively to a direct lexical influence. The independent contributions of biphone frequency and lexical neighborhood size to nonword recall performance demonstrated here indicate instead that the immediate recall of nonwords derives support not only from existing lexical representations but also from knowledge of the phonotactic regularities that characterize a language. Note that independent contributions of lexical and phonotactic representations have also been demonstrated in other language processing tasks, such as spoken word recognition (Vitevitch et al., 1999). However, whereas word recognition is enhanced by increased phonotactic frequency but inhibited by increased lexical neighborhood size, the present data indicate that both lexical and phonotactic long-term knowledge are beneficial to the immediate recall of nonword memory items.

What mechanisms are responsible for lexical and phonotactic long-term knowledge contributions to nonword recall? The influence of permanent lexical representations on immediate recall accuracy is well established. One of the most compelling demonstrations of this is observed in the recall advantage obtained for lists of words compared with nonwords (the lexicality effect, Hulme, Maughan, & Brown, 1991). The benefits of lexicality are widely attributed to the availability of permanent lexical representations for the reconstruction of degraded-word but not nonword memory traces, through a process termed *redintegration* (Hulme et al., 1991; Hulme, Newton, Cowan, Stuart, & Brown, 1999). One possibility is that the influence of lexical neighbors on nonword recall is also attributable to this redintegration process. The lexicality effect reflects the consequence of having an exact match for reconstruction of word but not nonword memory traces. However, redintegration of a degraded temporary memory trace might also be influenced by activation of similar or related lexical items. This type of influence could well extend to nonword recall, with multiple lexical representations influencing reconstruction of a temporary memory trace in a way that need not result in the output of a word. The beneficial effect of biphone frequency on nonword recall could also plausibly be mediated by a redintegration process, but one operating at the phonotactic rather than lexical level (Gathercole et al., 1999; Schweickert, 1993). In this case reconstruction might operate on a probabilistic basis, rather than with reference to specific lexical entries. Implicit knowledge of the phonotactic regularities of a language could facilitate reconstruction of nonwords composed of phoneme combinations that occur commonly in a language. A redintegrative account of the current findings would thereby view nonword recall as being supported by two separable reconstruction processes, one of which uses lexical representations to reconstruct degraded traces and a second process that uses knowledge of the phonotactic structure of a language. Note that these two putative redintegrative processes could also operate in the recall of words, but in this case the influence of the phonotactic reconstruction process might be overshadowed by the efficiency of the lexical reconstruction process.

Although consistent with a redintegrative account, the results of these experiments could also be accommodated by an account in which lexical neighborhood size and biphone frequency influences on nonword recall operate earlier in the memory process, during the storage of nonword memory items (Gathercole & Martin, 1996; Martin & Lesch, 1996; Martin, Shelton, & Yaffee, 1994). According to this view, long-term knowledge influences the representational quality and strength of a phoneme pattern in the temporary memory trace. One possibility is that short-term storage involves multiple temporary representations, reflecting properties of memory items such as their phonological structure and lexical-semantic content (Majerus, Van der Linden, Poncelet, & Metz-Lutz, 2004; Martin & Lesch, 1996; Martin et al., 1994). By this view, the representational quality and strength of memory items is determined by the strength of the component representations and the strength of connections between those representations. Thus, the lexicality effect is seen as reflecting the additional availability of lexical semantic representations for word but not nonword memory traces, providing connections that enhance the storage and hence likelihood of successful recall of words from STM. The lexical neighborhood size effect on nonword recall could arise in a similar way. In this case, a short-term phonological representation of a nonword might activate lexical semantic representations of words that are close lexical neighbors of that nonword, providing connections to the nonword's phonological representation. Nonwords with large lexical neighborhoods would thus activate larger numbers of lexical semantic representations than small-neighborhood nonwords, resulting in larger numbers of connections, in effect, increasing the strength of the phonological representation and hence accuracy of recall of the nonword from STM. The beneficial effects of biphone frequency, on the other hand, could arise more directly in this system through superior trace strength of the phonological representation for more commonly occurring phoneme patterns.

Note that the current findings of independent contributions of lexical neighborhood size and biphone frequency to nonword recall need not be attributed to a single mechanism and it is entirely plausible that these effects reflect dissociable mechanisms and processes. Common to both redintegrative and storage accounts of these effects, however, is the proposal that support from lexical neighbors arises when temporary memory processes are influenced by activation of permanent lexical representations, whereas phonotactic influences reflect the use of knowledge that is derived from the mental lexicon but is not associated with specific lexical activation.

In summary, irrespective of the precise mechanisms involved, the current experiments clearly demonstrate that the long-term knowledge contribution to serial recall of nonwords is not exclusively due to an influence of lexical items. The findings suggest instead two sources of support for the immediate recall of nonwords: one that uses knowledge of the lexical properties of a language to enhance nonword recall and another that uses knowledge of the phonotactic structure that characterizes a language.

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Appendix

Stimuli Used in Experiments 1 and 2

Stimuli Used in Experiment 1

Low biphone frequency				High biphone frequency			
Item	IPA	Item	IPA	Item	IPA	Item	IPA
jav	ʤæv	meeve	miːv	jeck	ʤɛk	moab	məʊb
juck	ʤʌk	meeze	miːz	jev	ʤɛv	naish	neɪʃ
bice	baɪs	nav	næv	barse	baːs	noave	nəʊv
boaf	bəʊf	noash	neʊʃ	baff	bæf	neek	niːk
boam	bəʊm	neff	nɛf	bam	bæm	noff	nɒf
bov	bɒv	nuck	nʌk	deg	dɛg	nop	nɒp
darb	dɑːb	nup	nʌp	fal	fæl	poave	pəʊv
dag	dæg	paim	peɪm	fide	faɪd	pum	pʌm
furse	fɜːs	rarl	rɑːl	foase	fəʊs	rark	rɑːk
fod	fɒd	rork	rɔːk	goace	gəʊs	rorl	rɔːl
fud	fʌd	sorm	sɔːm	harse	hɑːs	sibe	saɪb
haim	heɪm	sorp	sɔːp	hev	hɛv	sipe	saɪp
hais	heɪs	saff	sæf	hom	hɒm	surm	sɜːm
haiv	heɪv	soag	səʊg	koab	kəʊb	tep	tɛp
karb	kɑːb	tarl	tɑːl	kuv	kʌv	tull	tʌl
kive	kaɪv	vape	veɪp	lub	lʌb	vap	væp
lorb	lɔːb	vike	vaɪk	marse	mɑːs	vape	veɪk
murse	mɜːs	voam	vəʊm	mort	mɔːt	vurm	vɜːm
murt	mɜːt	wice	waɪs	maive	meɪv	wais	weɪs
meeb	miːb	weff	wɛf	mize	maɪz	woff	wɒf

Note. IPA = International Phonetic Alphabet.

Stimuli Used in Experiment 2

Large neighborhood size				Large neighborhood size			
Item	IPA	Item	IPA	Item	IPA	Item	IPA
barl	bɑːl	nugg	nʌg	judd	ʤʌd	rarl	rɑːl
berdge	bɜːʤ	peef	piːf	bive	baɪv	rarse	rɑːs
berl	bɜːl	rart	rɑːt	daff	dæf	rorsh	rɔːʃ
dake	deɪk	rorm	rɔːm	dach	dætʃ	rorse	rɔːs
dopp	dɒp	rorn	rɔːn	doab	dəʊb	sorg	sɔːg
dupp	dʌp	sab	sæb	deg	dɛg	sav	sæv
duss	dʌs	soave	səʊv	deef	diːf	sabe	seɪb
fave	feɪv	sutt	sʌt	fesh	fɛʃ	som	sɒm
fert	fɛːt	tarl	tɑːl	gidge	gɪʤ	tarb	tɑːb
gade	geɪd	tarm	tɑːm	gibb	gɪb	tarse	tɑːs
goan	gəʊn	torse	tɔːs	gupp	gʌp	terv	tɛːv
hib	hɪb	tash	tæʃ	kibe	kaɪb	toase	təʊs
karb	kɑːb	tuys	taɪs	lupp	lʌp	toave	təʊv
kerm	kɜːm	tuss	tʌs	meeve	miːv	vape	veɪp
koab	kəʊb	vag	væg	modge	mɒʤ	vike	vaɪk
lork	lɔːk	vake	veɪk	norg	nɔːg	verm	vɜːm
mave	meɪv	verd	vɜːd	noase	nəʊs	vert	vɜːt
nive	naɪv	voaz	vəʊz	noff	nɒf	voash	vəʊʃ
noave	nəʊv	weff	wɛf	nupp	nʌp	zake	zeɪk
neek	niːk	woff	wɒf	poave	pəʊv	zeff	zɛf

Note. IPA = International Phonetic Alphabet.

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