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Brief article

The KEY to the ROCK: Near-homophony in nonnative visual word recognition

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ABSTRACT

To test the hypothesis that native language (L1) phonology can affect the lexical representations of nonnative words, a visual semantic-relatedness decision task in English was given to native speakers and nonnative speakers whose L1 was Japanese or Arabic. In the critical conditions, the word pair contained a homophone or near-homophone of a semantically associated word, where a near-homophone was defined as a phonological neighbor involving a contrast absent in the speaker's L1 (e.g., ROCK–LOCK for native speakers of Japanese). In all participant groups, homophones elicited more false positive errors and slower processing than spelling controls. In the Japanese and Arabic groups, near-homophones also induced relatively more false positives and slower processing. The results show that, even when auditory perception is not involved, recognition of nonnative words and, by implication, their lexical representations are affected by the L1 phonology.

1. Introduction

It is well known that late bilinguals encounter difficulties in perceiving and producing the difference between sounds in a second language (L2) that are not contrastive in their native language (L1). The problem is most pronounced when the two L2 sounds are phonetically similar to a single phoneme in the L1 (Best, 1995; Bohn & Flege, 1992; Flege, 1995; Flege, Bohn, & Jang, 1997; Sebastián-Gallés & Soto-Faraco, 1999). The classic example is the case of English /l/ and /r/ for native speakers of Japanese, a language that lacks that contrast and has just one phoneme (/ɾ/) that corresponds to both /l/ and /r/ (Goto, 1971; MacKain, Best, & Strange, 1981; Mochizuki, 1981).

Recent research has begun to investigate the effects of such L1–L2 phonemic mismatch on L2 spoken word recognition. Unsurprisingly, late bilinguals exhibit indeterminacy between L2 words that differ by a nonnative contrast. For example, eye-tracking studies show that native Japanese speakers tend not to resolve the difference between English words such as *rocket* and *locker* until the second half of the word is heard (Cutler, Weber, & Otake, 2006). In auditory lexical decision tasks, Japanese speakers who have heard an English word including /l/ or /r/ (e.g., *light*) are faster in responding to its minimal-pair counterpart (e.g., *write*) (Cutler & Otake, 2004). Similar priming effects have been observed in native Dutch speakers processing English minimal pairs involving the non-Dutch contrast /æ/–/ɛ/ (e.g., *cattle* vs. *kettle*) (Weber & Cutler, 2004), and native Spanish speakers processing Catalan minimal pairs involving non-Spanish contrasts such as /e/–/ɛ/, /o/–/ɔ/ and /s/–/z/, (Pallier, Colomé, & Sebastián-Gallés, 2001; Sebastián-Gallés, Echeverría, & Bosch, 2005), an effect also consistent with ERP evidence (Sebastián-Gallés, Rodríguez-Fornells, de Diego-Balaguer, & Díaz, 2006).

These cross-lexical effects may be products of indeterminate lexical representations, as suggested by researchers mentioned in the previous paragraph. According to this interpretation, the phonological representations of *lock* vs. *rock* may not be completely separate in the Japanese–English bilinguals' mental lexicon, making the words func-

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tionally homophonous. However, the observed effects may also be the result of phonetic misperception of the nonnative sounds. For instance, native speakers of Japanese listening to English words containing /l/ or /r/ may simply fail to decode the relevant speech signals, and thus misperceive [lɑk] as [rɑk]. In a spoken word recognition task, such effects of prelexical misperception are difficult to separate from those of indeterminate lexical representations because comprehension of speech materials inherently involves processing of auditory input.

In order to avoid such a confound between perception and representation, we have devised an experiment that builds on findings from visual word recognition research. A range of experimental evidence shows that (monolingual) readers automatically access the phonological information of orthographically presented words (see Frost, 1998, for a comprehensive review). For instance, exposure to written words speeds up or improves the subsequent identification of phonologically identical words (e.g., Drieghe & Brysbaert, 2002; Grainger & Ferrand, 1994; Lukatela & Turvey, 1990; Lukatela & Turvey, 1994; Perfetti & Bell, 1991). Furthermore, it has been demonstrated that access to the meaning of visual words is mediated by the phonology of the lexical item. When asked to judge whether a word is a member of a particular semantic category (e.g., A FLOWER), participants tend to make more false positive errors for homophones and pseudo-homophones (e.g., ROWS or ROWZ for ROSE) than for spelling-matched controls (e.g., ROBS) (Van Orden, 1987; Van Orden, Johnston, & Hale, 1988; Van Orden, Pennington, & Stone, 1990). Similarly, in judging whether two visual words are semantically related, participants are less accurate and slower in rejecting unrelated word pairs that involve homophones (e.g., LION–BARE) or pseudohomophones (e.g., TABLE–CHARE) than pairs involving their visual controls (e.g., LION–BEAN, TABLE–CHARK) (Lesch & Pollatsek, 1998; Luo, Johnson, & Gallo, 1998). The indication is that viewing a visual word (e.g., BARE) activates its phonological representation (/bɛə(r)/, which in turn activates its homophone (*bear*) and causes the semantic interference.

In the experiment reported below, we exploited this mechanism of phonological mediation in visual word recognition to examine the effects of L1 phonology on L2 lexical representations without using auditory stimuli. We hypothesized that, if a lack of contrast in the L1 renders L2 words functionally homophonous, the same kind of homophone effects found in monolingual visual word recognition should also be induced in nonnative speakers by L2 minimal pairs on a nonnative contrast (e.g., LOCK and ROCK for native speakers of Japanese). We call such words near-homophones. The specific task we employed was the semantic-relatedness judgment used in Luo et al. (1998). Our reasoning predicts there to be relatively more false positive errors and slower processing for pairs involving near-homophones (e.g., KEY–ROCK) than for those involving spelling controls (e.g., KEY–SOCK).

We tested two groups of nonnative English speakers with different L1s, Japanese and Arabic, as well as native speakers of English as a control group. The two L1s are complementary with respect to the critical English phonemic contrasts we tested: /l/–/r/ (lacking only in Japanese) and /p/–/b/ (lacking only in Arabic). The two L1s were chosen also because neither one of them uses the Roman alphabet as their standard script. This prevented the nonnative speakers from accessing their native language grapheme-phoneme correspondence rules during recognition of L2 visual words, a process known to occur in bilingual reading when the L1 and L2 share the same script (Brysbaert, Van Dyck, & Van de Poel, 1999; Dijkstra, Grainger, & Van Heuven, 1999; Haigh & Jared, 2007; Lemhöfer & Dijkstra, 2004). On the other hand, by selecting L1s that do not use Roman-alphabetic writing, we may have risked the possibility of studying nonnative speakers who may not access phonological information when reading L2 English words at all. In order to check that our nonnative participants did indeed generally engage in phonological processing while reading English words, we also tested their recognition of real homophones, where genuine homophone effects were expected.

Measures were taken to control for two other extraneous factors. First, since having separate lexical representations for words containing a nonnative contrast is contingent on knowing such a contrast, we excluded nonnative speakers who were incapable of performing above chance level in a phoneme identification task involving the critical English contrasts. Second, homophone confusion errors in visual word tasks may not only reflect phonological mediation but also participants' inaccurate orthographic-lexical knowledge (Coltheart, Patterson, & Leahy, 1994; Starr & Fleming, 2001). To minimize the impact of this factor, we tested our participants' orthographic knowledge of the stimulus words offline, and only included their response to a particular word in the semantic-relatedness decision task if it had been correctly answered in the off-line task.

In sum, the goal of this study was to present evidence independent of perceptual effects that lack of L2 contrasts in the L1 can lead to indeterminacy in phonological representations of L2 words in the mental lexicon. We set out to test this hypothesis in a semantic-relatedness decision task designed after Luo et al. (1998). Our predictions were as follows. Participants in all three groups should produce larger false positive error rates and slower reaction times for homophones in comparison to their spelling controls. The Japanese speakers should also produce relatively large false positive error rates and slow reaction times for /l–r/ near-homophones. Conversely, the Arabic speakers should produce relatively large false positive error rates and slow reaction times for /p–b/ near-homophones.

2. Method

2.1. Participants

Participants consisted of 20 native speakers of English (18 females and 2 males), 20 native speakers of Japanese (16 females and 4 males), and 20 native speakers of Arabic (8 females and 12 males). All native speakers of English, 15 of the Japanese speakers, and 13 of the Arabic speakers were university students. On average, the Japanese speakers had lived in English-speaking countries for 3;6 years (range 1;3–11;6) and the Arabic speakers for 5;0 years (range 0;3–26;0). Eighteen of the Japanese speakers and 16 of the Arabic speakers reported using English as much or more often than their native language on a daily basis.

There were 22 other nonnative (6 Japanese and 16 Arabic) speakers who volunteered but did not participate in the main experiment because they did not meet the inclusion criterion set for a screening test, which was a two-alternative forced choice matching task involving auditory and visual nonsense syllables. The critical items were /la/, /ra/, /lɛŋk/ and /rɛŋk/ for the /l/–/r/ contrast, and /pa/, /ba/, /pɛŋk/ and /bɛŋk/ for the /p/–/b/ contrast. Each item was auditorily presented and followed by two visually presented syllables in block letters, one that matched the auditory syllable and one that matched the other member of the minimal pair (e.g., <LENK> and <RENK>). The test consisted of 32 such trials (16 for each critical contrast) and 96 filler trials. Only participants that performed above chance level (i.e., 11 out of 16) for both critical contrasts, /l/–/r/ and /p/–/b/, were invited to take part in the semantic-relatedness decision task.

2.2. Materials

The experimental stimuli were constructed from 20 homophone pairs (e.g., SON-SUN), 20 /l–r/ minimal pairs (e.g., LOCK–ROCK) and 20 /p–b/ minimal pairs (e.g., PEACH–BEACH). A minimally different spelling control was coupled to each pair (e.g., SOCK for LOCK–ROCK), with the constraints that the control differed in only a single grapheme from either member of the pair and that its phonological difference from each member of the pair would not involve a contrast missing in Japanese or Arabic. To compensate for the large difference in orthography between some pair members, we used separate spelling controls for such items (e.g., BRAKE (BRAVE)–BREAK (BREAD)). For each contrast, the homophone or minimal pairs and the spelling controls were approximately equated in terms of frequency (based on the wordform frequency in the CELEX database; Baayen, Piepenbrock, & Van Rijn, 1993) as well as numbers of orthographic and phonological neighbors (based on the English Lexicon Project; Balota et al., 2007). A complete list of experimental words and their spelling controls is given in the Appendix.

For each triplet (homophone or minimal pair and its control), we created four word pairs for the semantic-relatedness decision task by combining each member of the homophone or minimal pair with the semantic associate of its counterpart and also by combining the spelling control with the two semantic associates. For example, from the triplet LOCK–ROCK–SOCK we constructed LOCK–HARD (HARD is an associate of ROCK), ROCK–KEY (KEY is an associate of LOCK), SOCK–HARD, and SOCK–KEY. Thus, the same semantic foil (e.g., KEY) was combined with an experimental item (ROCK) and also with its spelling control (SOCK). These word pairs were divided into four 120 item lists, to which participants were randomly assigned. Each participant saw only one member of each homophone or minimal pair along with its spelling control. So for instance, one participant may have seen KEY–ROCK (and KEY–SOCK) but not HARD–LOCK (or HARD–SOCK). The presentation position (i.e., left/right of the screen) of the experimental item was counterbalanced across lists.

In addition to these critical word pairs, each participant saw 240 filler pairs. Of these, 180 pairs were semantically related (e.g., DOCTOR–NURSE) and the remaining 60 pairs were unrelated (e.g., PHONE–SHEEP). Since all the 120 experimental word pairs presented to a participant were semantically unrelated, exactly half of the complete set of experimental and filler items each participant saw required a 'yes' (i.e., 'related') response.

2.3. Procedure

Each trial began with a fixation point presented in the center of the screen for 1000 ms, followed by two words, which were juxtaposed horizontally, center-aligned, and remained on screen until the participant pressed a button. The participants were asked to judge whether the two words were semantically related. They responded by pushing the <l> ('yes') or <a> ('no') key on the keyboard. The stimulus words were presented in an 18 point bold Arial font. The session began with 20 practice trials.

After the semantic-relatedness decision task, participants proceeded to a lexical knowledge test involving all of the experimental stimuli and spelling controls used in the main task. The test was presented as an untimed, self-paced web questionnaire. Each target appeared in bold typeface next to three words, one of which was a near-synonym of the target.

3. Results

3.1. Accuracy

Items for which participants made errors in the lexical knowledge test were excluded (along with their matched observations) from the error analysis of the semantic-relatedness decision task. These accounted for the exclusion of 9 responses (0.8%) from the native English group, 192 responses (8.0%) from the Japanese speaker group, and 520

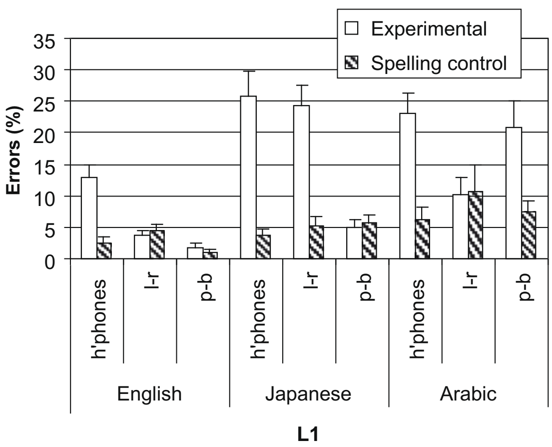

Fig. 1. Mean percentage of errors (by participants). Error bars indicate +1 standard error of the mean.

Table 1
Three-way ANOVA results of the mean error rates.

Effect	Analysis			
	By participants		By items	
	df	*F1*	*df*	*F2*
Group	2, 57	7.44***	2, 351	18, 64***
Contrast	2, 114	13.41***	2, 351	11, 15***
Condition	1, 57	92.85***	1, 351	101.80***
Group × Contrast	4, 114	7.06***	4, 351	5.01***
Group × Condition	2, 57	19.10***	2, 351	11.14***
Contrast × Condition	2, 114	13.41***	2, 351	18.97***
Group × Contrast × Condition	4, 114	11.06***	4, 351	8.99***

*** $p < 0.001$.

responses (21.6%) from the Arabic speaker group. Mean error rates based on the remaining data are shown in Fig. 1.

We first conducted a Group (English vs. Japanese vs. Arabic) × Contrast (homophone vs. /l–r/ vs. /p–b/) × Condition (experimental item vs. spelling control) mixed ANOVA of the mean error rates. The analysis revealed a significant Group × Contrast × Condition interaction (Table 1).

To pull apart the three-way interaction, a two-way ANOVA was conducted for each language group. In all three groups, a significant Contrast × Condition interaction was found (Table 2).

A planned comparison showed that the native English speaker group produced more errors in the homophone condition than in the corresponding spelling control condition [$t_1(19) = 7.24$, $p < 0.001$; $t_2(39) = 3.55$, $p < 0.001$]. The Japanese group produced more errors in the experimental condition than in the corresponding spelling control condition for the homophone items [$t_1(19) = 5.85$, $p < 0.001$; $t_2(39) = 7.17$, $p < 0.001$] and the /l–r/ items [$t_1(19) = 6.00$, $p < 0.001$; $t_2(39) = 5.52$, $p < 0.001$]. The Arabic group produced more errors in the experimental condition than in their spelling control condition for the homophone items [$t_1(19) = 5.88$, $p < 0.001$; $t_2(39) = 5.35$, $p < 0.001$] and the /p–b/ items [$t_1(19) = 4.03$, $p < 0.001$; $t_2(39) = 3.98$, $p < 0.001$]. No difference was found between the experimental items and their spelling controls in any other language-contrast combinations [all *t*s < 1].

Table 2
Two-way ANOVA results of the mean error rates.

Group	Effect	Analysis			
		By participants		By items	
		df	*F1*	*df*	*F2*
English	Contrast	2, 38	12.04***	2, 117	7.51***
	Condition	1, 19	37.21***	1, 117	9.28**
	Contrast × Condition	2, 38	25.93***	2, 117	10.24***
Japanese	Contrast	2, 38	16.58***	2, 117	8.47***
	Condition	1, 19	59.31***	1, 117	61.13***
	Contrast × Condition	2, 38	16.17***	2, 117	16.76***
Arabic	Contrast	2, 38	2.25	2, 117	4.19*
	Condition	1, 19	22.65***	1, 117	34.64***
	Contrast × Condition	2, 38	9.19***	2, 117	8.25***

* $p < .05$.
** $p < .01$.
*** $p < .001$.

3.2. Latency

The reaction time analysis excluded observations that were errors or outliers (>10,000 ms). This resulted in the exclusion of 4.4% of the native English data, 12.5% of the Japanese speakers' data, and 11.8% of the Arabic speakers' data. To further reduce the impact of extreme reaction times, we used medians for each participant and item. Summary latency data are shown in Fig. 2.

As with the error data we first conducted a Group × Contrast × Condition mixed ANOVA of the median reaction times. The analysis revealed a three-way Group × Contrast × Condition interaction, significant by items and marginal by participants (Table 3).

A Contrast × Condition ANOVA conducted for each language group showed that the Contrast × Condition interaction was significant by participants in the English group, marginally significant by items in the Japanese group, and significant by items and marginal by participants in the Arabic group (Table 4).

Planned comparisons showed that, in the English group, homophones were rejected significantly slower than matched control items by participants (and marginally by items) [$t_1(19) = 2.66$, $p < 0.05$; $t_2(39) = 1.72$, $p = 0.09$]. In

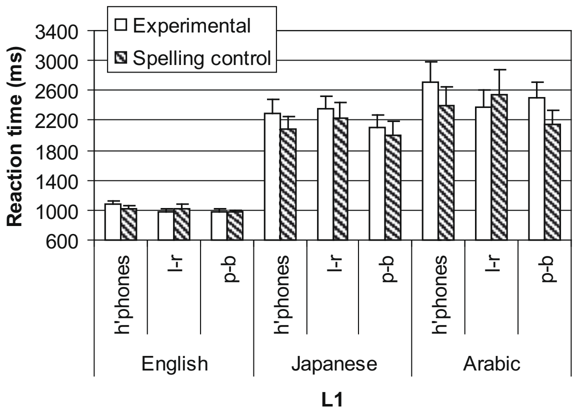

Fig. 2. Mean response latencies (by participants). Error bars indicate +1 standard error of the mean.

Table 3
Three-way ANOVA results of the median reaction times.

Effect	Analysis			
	By participants		By items	
	df	*F1*	*df*	*F2*
Group	2, 56	27.57***	2, 351	369.30***
Contrast	2, 114	2.02	2, 351	6.73***
Condition	1, 56	8.90**	1, 351	28.57***
Group × Contrast	4, 112	2.77*	4, 351	2.76*
Group × Condition	2, 56	1.94	2, 351	5.61**
Contrast × Condition	2, 112	3.91*	2, 351	3.72*
Group × Contrast × Condition	4, 112	2.11±	4, 351	3.15*

± $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 4
Two-way ANOVA results of the median reaction times.

Group	Effect	Analysis			
		By participants		By items	
		df	*F1*	*df*	*F2*
English	Contrast	2, 38	7.11**	2, 117	6.20**
	Condition	1, 19	0.64	1, 117	2.41
	Contrast × Condition	2, 38	6.28**	2, 117	1.20
Japanese	Contrast	2, 38	6.26**	2, 117	5.28**
	Condition	1, 19	3.26±	1, 117	17.15***
	Contrast × Condition	2, 38	0.89	2, 117	3.02±
Arabic	Contrast	2, 36	1.04	2, 117	2.94±
	Condition	1, 18	5.36*	1, 117	10.20**
	Contrast × Condition	2, 36	3.00±	2, 117	3.73*

± $p < 0.10$.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

the Japanese group, experimental items were rejected significantly slower than spelling controls for homophones [$t_1(19) = 3.06$, $p < 0.01$; $t_2(39) = 3.10$, $p < 0.01$] and for /l–r/ items (by items) [$t_2(39) = 2.68$, $p < 0.05$]. In the Arabic group, experimental items were rejected significantly slower than their spelling controls in the homophone condition [$t_1(19) = 2.32$, $p < 0.05$; $t_2(39) = 2.49$, $p < 0.05$], and in the /p–b/ condition [$t_1(18) = 2.87$, $p < 0.01$; $t_2(39) = 3.69$, $p < 0.01$] (One participant with 0 valid observation was excluded from the by-participants comparison for /p–b/). No difference was found between the experimental items and spelling controls in any other language-contrast pairs (all *ts* < 1, except $t_1(19) = 1.87$, $p = 0.08$ for the English /l–r/ contrast, $t_1(19) = 1.02$, $p = 0.32$ for the Japanese /p–b/ contrast, and $t_1(19) = 1.12$, $p = 0.28$ for the Arabic /l–r/ contrast).

4. Discussion

Our first prediction was that participants in all three groups would produce higher error rates and slower reaction times for word pairs involving real homophones than their spelling controls. This was largely supported by the data. These results replicate the findings of Luo et al. (1998) and extend them to nonnative visual word recognition. In other words, phonological mediation occurs in L2 visual word recognition too.

This outcome has provided us with the empirical foundation to test the other prediction we made, which was that near-homophones would produce homophone-like effects in nonnative speakers. The data confirmed this prediction too. More false positive errors and slower reaction times were elicited by the experimental items than their corresponding spelling controls in the /l–r/ condition of the Japanese group and the /p–b/ condition of the Arabic group. No such effect was obtained in the /p–b/ condition of the Japanese group or the /l–r/ condition of the Arabic group. This double dissociation between the Japanese and Arabic group shows that homophone-like effects are revealed exactly and only in the condition with minimal pairs that involve a missing phonemic contrast in the L1.

The outcomes of our experiment provide direct evidence that transfer of L1 phonology can occur not only in the perception and articulation of L2 sounds, but also in the phonological coding of L2 lexical entries. Since the tasks employed in the current study involved only visual recognition, the observed cross-lexical activation cannot be attributed to auditory misperception. Our study, therefore, offers support for the representational interpretation taken by Pallier et al. (2001), Sebastián-Gallés et al. (2005) and Cutler et al. (2006) of their L2 spoken word recognition results. The lexicon of late bilinguals indeed fails in completely separating L2 lexical entries that involve nonnative phonological contrasts. What is striking about our finding is that the effects of such representational indeterminacy are felt even in written word recognition where the distinction between the word forms is marked by visual information, which in principle should be accessible to readers regardless of their inventory of early acquired phonemic systems.

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Appendix List. of homophones, minimal pairs, and spelling controls

Homophones/minimal pairs		Spelling controls
Homophone condition		
BRAKE	BREAK	BRAVE/BREAD
BUY	BYE	BOY/BEE
CELL	SELL	TELL
FLOUR	FLOWER	FLOOR/FOLDER
HEAL	HEEL	HELL
HEAR	HERE	HEIR/HIRE
MADE	MAID	MAZE/MAIN
MAIL	MALE	MALL
MEAT	MEET	MELT
MINOR	MINER	MIRROR
PEACE	PIECE	PENCE/NIECE
SAIL	SALE	SOIL/SALT
SEA	SEE	SET
SIGHT	CITE	FIGHT/BITE
SOLE	SOUL	SOLO/SOUP
SON	SUN	SIN
STEAL	STEEL	STEAM/STEEP
TAIL	TALE	TALL
WAIST	WASTE	WRIST/TASTE
WEAK	WEEK	WEAR/WEED

(*continued on next page*)

Appendix (*continued*)

Homophones/minimal pairs		Spelling controls
l–r condition		
CLAP	CRAP	CHAP
CLOUD	CROWD	CHORD
COLLECT	CORRECT	CONNECT
ELECT	ERECT	EJECT
LACK	RACK	SACK
LAG	RAG	TAG
LANE	RAIN	SANE/PAIN
LAP	RAP	MAP
LATE	RATE	MATE
LAW	RAW	SAW
LAY	RAY	DAY
LED	RED	BED
LIGHT	RIGHT	TIGHT
LIP	RIP	DIP
LIVER	RIVER	DIVER
LOAD	ROAD	TOAD
LOCK	ROCK	SOCK
LONG	WRONG	SONG/AMONG
LOT	ROT	POT
LUST	RUST	DUST
p–b condition		
PAD	BAD	MAD
PAN	BAN	MAN
PARK	BARK	MARK
PAT	BAT	FAT
PATH	BATH	MATH
PAY	BAY	SAY
PEACH	BEACH	REACH
PEAK	BEAK	LEAK
PEAR	BEAR	FEAR
PEER	BEER	DEER
PET	BET	JET
PIG	BIG	DIG
PILL	BILL	HILL
PIN	BIN	WIN
PIT	BIT	WIT
POND	BOND	FOND
POUND	BOUND	SOUND
PULL	BULL	DULL
PUMP	BUMP	DUMP
PUNCH	BUNCH	LUNCH

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