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A prerequisite to L1 homophone effects in L2 spoken-word recognition

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Abstract

When both members of a phonemic contrast in L2 (second language) are perceptually mapped to a single phoneme in one's L1 (first language), L2 words containing a member of that contrast can spuriously activate L2 words in spoken-word recognition. For example, upon hearing *cattle*, Dutch speakers of English are reported to experience activation of *kettle*, as L1 Dutch speakers perceptually map the vowel in the two English words to a single vowel phoneme in their L1. In an auditory word-learning experiment using Greek and Japanese speakers of English, we asked whether such cross-lexical activation in L2 spoken-word recognition necessarily involves inaccurate perception by the L2 listeners, or can also arise from interference from L1 phonology at an abstract level, independent of the listeners' phonetic processing abilities. Results suggest that spurious activation of L2 words containing L2-specific contrasts in spoken-word recognition is contingent on the L2 listeners' inadequate phonetic processing abilities.

Keywords

English, Greek, Japanese, L1 phonology, L2 spoken-word recognition, phonetic processing

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1 Introduction

Research on second language (L2) speech perception has shown that various L2 phonemic contrasts do not pose the same degree of challenge to L2 learners. Since the 1990s, many studies have shown that it is difficult to learn to discriminate L2 phonemes when the contrasting phonemes are perceived by the L2 listeners to be similar to a single phoneme in their first language (L1), while L2 phonemes perceived to be similar to different L1 phonemes are easy to discriminate (hereafter 'difficult' vs. 'easy' L2 contrasts), consistent with Best's Perceptual Assimilation Model (Best, 1991; Best and Tyler, 2007). Difficult L2 contrasts include the English /l/ vs. /r/ in syllable-initial position for L1 Japanese listeners, who would perceptually map both phonemes to the only liquid sound /ɾ/ in Japanese (see Aoyama et al., 2004, and references therein), and the English /ɛ/ vs. /æ/ contrast for L1 Dutch listeners, who would perceptually map both vowels to the Dutch /ɛ/ (Cutler et al., 2005). Easy L2 contrasts include the English /w/ vs. /j/ for L1 Japanese listeners, who would perceptually map each of the English phonemes to /w/ vs. /j/ in their L1 (Best and Strange, 1992).

As one would expect, difficult L2 phonemic contrasts have been shown to produce non-native like behaviour in L2 spoken-word recognition. Specifically, minimal-pair words differing by a difficult L2 contrast (e.g. *lock* and *rock* for the Japanese; *kettle* and *cattle* for the Dutch) appear to be treated as if they were homophonous in L2 spoken-word recognition. In an auditory lexical decision task, the presentation of a member of such a minimal pair can facilitate the recognition of the other member (Broersma, 2002; Pallier et al., 2001; see, however, Broersma, 2012, for the observation of both facilitation and inhibition). Nonwords that differ from real words by a difficult L2 contrast (e.g. *geng* /gɛŋ/ vs. *gang* /gæŋ/ for L1 Dutch listeners) tend to be falsely identified as real words (Broersma, 2002). Eye-tracking evidence shows activation of spurious competitors upon the presentation of spoken words containing a member of difficult L2 contrasts (e.g. *rocket* initially activates *locker* in L1 Japanese listeners; see Cutler et al., 2006; Escudero et al., 2008; Weber and Cutler, 2004). We will refer to minimal-pair L2 words differing by a difficult L2 contrast as 'L1 homophones', and simultaneous activations of L1 homophones (e.g. *lock* and *rock* for Japanese listeners) and words containing such minimal-pair phoneme sequences (e.g. *locker* and *rocket* for Japanese listeners) in L2 lexical access as 'L1 homophone effects'.

Though they may not agree on other details, many researchers hold the view that L1 homophone effects are contingent on the L2 listeners' inabilities to distinguish L2 phonemic contrasts reliably. That is, L1 homophone effects occur only when the L2 listeners cannot fully distinguish the relevant L2 phonemic contrasts. For example, Cutler et al. (2006) and Weber and Cutler (2004) propose that L2 listeners distinguish L1 homophones at the representational level but their phonetic processing fails to deliver the correct mapping between auditory input and lexical representations. Broersma (2012), on the other hand, entertains the possibility that L1 homophones share a single phonological representation (see also Pallier et al., 2001). However, Broersma (2012) is in agreement with Cutler et al. (2006) and Weber and Cutler (2004) that L1 homophone effects arise from L2 listeners' lack of abilities to distinguish difficult L2 contrasts reliably. Notice that these researchers agree that the L2 listener's inadequate ability to distinguish an L2 phonemic contrast is necessary for an L1 homophone effect, and not that the L2 listener's inability to distinguish an L2 contrast always leads to an L1 homophone effect. As observed by Weber and Cutler (2004) and Cutler et al. (2006), L1 homophone effects can be asymmetrical (i.e. limited to words containing only one of the difficult L2 contrasts; see also Escudero et al., 2008). Darcy et al.'s (2012) L2 phonological acquisition model (direct mapping from acoustics to phonology, or 'DMAP') also regards L2 listeners' inabilities to discriminate difficult L2 contrasts as a necessary, though not a sufficient, condition for L1 homophone effects.

If L1 homophone effects are contingent on L2 listener's lack of abilities to distinguish difficult L2 contrasts, one would expect the effects to diminish or even disappear with experience, at least for some contrasts, considering observations of more native-like perceptual discrimination of L2 contrasts by learners with more L2 experience (Brown 2000; Escudero and Boersma, 2004; Escudero 2009). However, research to date has mainly shown that L1 homophone effects (symmetrical or asymmetrical) can be found in L2 listeners of a range of proficiency, including highly fluent Spanish–Catalan bilinguals in Pallier et al. (2001). Broersma (2012) observed an occasional lack of L1 homophone effects in a cross-modal priming experiment using proficient Dutch L2 speakers of English, which she attributed to the participants' accurate perception of the prime. Whether Broersma's (2012) interpretation is correct remains an empirical question, however, as how her L2 participants perceived the primes was not examined in that study.

Ota et al.'s (2009) study provides another piece of evidence that motivates an investigation into the contingency of L1 homophone effects on L2 listeners' lack of abilities to discriminate difficult L2 contrasts. In a semantic-relatedness task using orthographic words only, Ota et al. (2009) observed L1 homophone effects for minimal-pair English words differing by /p/ vs. /b/ (e.g. *bad* vs. *pad*) in L1 Arabic speakers, and for words differing by /l/ vs. /r/ (e.g. *lock* vs. *rock*) in L1 Japanese speakers. As Ota et al. (2009) pointed out, the observed L1 homophone effects could not have been directly caused by the L2 participants' lack of ability to discriminate the difficult L2 contrast, as the stimuli were presented in print.

Ota et al.'s (2009) findings are consistent with two possibilities. One possibility is that L1 homophone effects can occur independently of L2 listeners' abilities to discriminate difficult L2 contrasts. Given that cross-language phonological priming can be found in bilinguals regardless of their level of proficiency in L2 (Duyck et al. 2004; Zhou et al. 2010; see, however, Ju and Luce 2004), it may be that a two-to-one mapping between L2 and L1 phonemes at an abstract phonological level can directly trigger L1 homophone effects. Another possibility is that L1 homophone effects can be caused indirectly by L2 listeners' inadequate phonetic processing abilities. For example, the effects can occur without auditory input if L2 listeners who cannot reliably distinguish a difficult contrast have a single phonological representation (Broersma, 2012; Pallier et al., 2001) or ambiguous phonological representations (Ota et al., 2009) for L2 words that contain a member of that contrast. In the first scenario, L1 homophone effects will never entirely disappear, even if the L2 listener has become capable of distinguishing the difficult L2 contrast with native-like accuracy. In the second scenario, L1 homophone effects should diminish or disappear, as the L2 listener becomes better at distinguishing the difficult L2 contrast. Ota et al.'s (2009) results do not allow us to distinguish the two possibilities, as their L2 participants could not identify the critical L2 contrasts in auditory stimuli at a native-speaker level.

In this study we asked whether L1 homophone effects can occur purely due to a mismatch between L1 and L2 phonology at an abstract level, or whether the effects are contingent on L2 listeners' lack of abilities to distinguish difficult L2 contrasts. To our knowledge, no published work has examined the effect of L1 on lexical access in L2 listeners who have demonstrably learned to distinguish difficult L2 contrasts as accurately as native speakers. For instance, we do not know whether Pallier et al.'s (2001) highly fluent Spanish-dominant bilinguals could reliably distinguish the difficult Catalan contrasts used in that study. We therefore investigated whether L1 homophone effects can be observed in the recognition of spoken English words by L1 Greek and Japanese listeners who could distinguish the English /s/ vs. /ʃ/ and /b/ vs. /v/ contrasts in the stimuli with native-like accuracy. The English /s/ and /ʃ/ were both expected to be mapped to a single Greek phoneme /s/ by L1 Greek listeners, because Greek lacks /ʃ/ and its /s/ is phonetically in between the English /s/ and /ʃ/ (Arvaniti, 2007). The English /b/ and /v/ were expected to be mapped to a single Japanese phoneme /b/ by L1 Japanese listeners, whose L1 lacks /v/ (Brown, 2000; Vance, 2008).

The L2 participants were studied in a word learning experiment similar to Lindsay and Gaskell's (2013), a condensed version of Gaskell and Dumay's (2003) word learning experiment. In those studies, the offset of existing words (e.g. *slogan*) were altered to create novel words (e.g. *slowgiss*) for participants to learn through repeated auditory exposure. Learning novel words (*slowgiss* in the above example) interfered with the recognition of the base word (i.e. *slogan*) in an auditory lexical decision task, an effect attributed to the competition from the novel word, whose initial portion was identical to that of the base word (see, for example, Norris et al., 1995). We chose an auditory word-learning task, so that the lexical representations of novel words (described below) would be built without reliance on orthographic information, which has been shown to affect the L2 spoken-word recognition process (Escudero et al., 2008).

In order to tap into possible Greek and Japanese L1 homophone effects, additional novel words were designed. The additional words were created by altering the onset *and* offset of English words beginning with /s/ or /ʃ/ (a contrast lacking in Greek) and words beginning with /b/ or /v/ (a contrast lacking in Japanese). For example, *shentimemp* was derived from *sentiment*, and *venefup* from *benefit*. In Greek, a language which does not distinguish /s/ from /ʃ/, L1 homophone effects should lead to interference in the recognition of *sentiment* due to competition from *shentimemp*, Under Greek L1 homophone effects, which do not distinguish /s/ from /ʃ/, competition from *shentimemp* should interfere with the recognition of *sentiment*, as the initial portion of the two words are homophonous. Likewise, in Japanese, a language which does not distinguish /b/ from /v/, L1 homophone effects should lead to interference in the recognition of *benefit* due to competition from *venefup*. L1 English participants' recognition of *benefit* and *sentiment* should be less affected by these novel words, because *benefit* and *venefup*, and *sentiment* and *shentimemp* start with different English phonemes (Gaskell and Dumay, 2003).

II Methods

1 Participants

Three participant groups were tested: (1) L1 English participants, (2) L1 Greek participants and (3) L1 Japanese participants. The Greek and Japanese participants were recruited through advertisements asking for native speakers of each language who had mainly grown up in Greece or Japan, but had lived in an English-speaking country (or countries) for at least six months, and had no history of speech or hearing problems. They were screened using an onset-phoneme monitoring task (described below) to ensure that they can identify each member of the difficult L2 test contrast (/s/ vs. /ʃ/ for Greek; /b/ vs. /v/ for Japanese) in the novel words to be learned with native-like accuracy. Eighteen L1 English, 29 Greek and 32 Japanese participants took the screening test. Of those, 18 from each group passed the test (English: 7 males and 11 females; Greek: 7 males and 11 females; Japanese: 3 males and 15 females). Greek participants who failed the screening had difficulty with the /s/ vs. /ʃ/ contrast, and Japanese participants with the /b/ vs. /v/ contrast, consistent with our assumption that the English /s/ and /ʃ/ are confusable for the Greek listeners, and /b/ and /v/ for the Japanese listeners.

The mean age of the participants who passed the screening was 27 years for L1 English, 26 for Greek and 27 for Japanese. In a post-experiment questionnaire, all participants confirmed that their first language was that of the language group they were assigned to (English, Greek or Japanese). The mean age at which the Greek and Japanese participants moved to an English-speaking country from their country of birth (Greece or Japan) was 24 and 23 years, respectively. In other words, they had lived in English-speaking countries on average for two and four years at the time of the experiment. According to their self-reported English proficiency, 3 Greek and Japanese participants each were ‘near native’, 14 Greek and 9 Japanese participants ‘advanced’, and 1 Greek and 6 Japanese participants ‘intermediate’[1] (see Appendix 1 for information regarding individual participants.)

All participants either had or were working towards a university undergraduate degree. Of those already with an undergraduate degree, six English, eight Greek and five Japanese participants either had or were working towards a PhD.

2 Stimuli

Thirty-six words were chosen as base words for an auditory lexical decision task (see Table 1 for examples, and Appendix 2 for the whole list). Each six of the base words had one of six test phonemes (/b/, /d/, /m/, /s/, /ʃ/ and /v/) as a simplex onset. As explained earlier, /s/ vs. /ʃ/ is a contrast lacking in Greek, while /b/ vs. /v/ is a contrast lacking in Japanese. These four phonemes (/b/, /s/, /ʃ/ and /v/) appeared in the onset of the base words only. Words beginning with /d/ and /m/ were included as base words beginning with a phoneme present in all three languages.

In selecting base words, we consulted the results of an informal word familiarity questionnaire given to 30 overseas postgraduate students residing in the UK, so that the majority of the base words were likely to be known by our L2 participants. All base words had 2 to 4 syllables (M = 2.7) and 5 to 9 phonemes (M = 6.5). They all had a uniqueness point before the final segment. Common loanwords in Greek or Japanese starting with the L2-specific phoneme (/ʃ/ for Greek and /v/ for Japanese, e.g. *shampoo* and *vitamin*) were avoided.

As exemplified in Table 1, from base words starting with /d/ or /m/, novel words were created by either altering the final two segments of the word (e.g. *document* →

Table 1. Example stimuli used in each task.

Word type	Phoneme monitoring (novel words)	Stem completion (novel words)	Lexical decision (base words)
b/v onset	venefop	venefop	benefit
	bictift	bictift	victim
d/m onset	documemp	documemp	document
	madonid	madonid	Madonna
s/sh onset	shentimemp	shentimemp	sentiment
	sepon	sepon	shepherd
Control	n/a	n/a	picnic

documemp), or altering the final segment and adding a consonant (e.g. *Madonna* → *madonid*). As for base words starting with /b/ or /v/, their onset was first altered, so that they would constitute L1 homophones for the Japanese (e.g. *benefit* → *venefit, victim* → *bictim*). Then, their offset was altered in the same way as the base words starting with /d/ or /m/ (e.g. *venefit* → *venefop, bictim* → *bictift*). Novel words starting with /s/ or /ʃ/ were created in the same way (e.g. *sentiment* → *shentiment* → *shentimemp*).[2] The novel words were divided into two counterbalanced lists, with each participant learning 18 items.

Twenty-one additional English words were chosen as control words, to be presented in the lexical decision task alongside the base words (see Table 1 above and Appendix 3). No novel words were created from the control words. The change in participants' responses to the control words over the course of the experiment was used as the baseline in assessing the emergence of lexical competition from novel words for the base words, as the control words would not have new lexical competitors resulting from the experiment.

Additionally, 39 nonwords were created for the lexical decision task, in which real-word and nonword items were presented equally often (see Appendix 4). Nonwords were created by altering the offset of existing words that were not used as base or control words. For example, *segmemph* was created from *segment*, and *vouchet* from *voucher* (some of the nonwords were adapted from Gaskell and Dumay, 2003, and Lindsay and Gaskell, 2013) Care was taken that participants would not be able to detect the lexical status of the stimuli in the lexical decision task without processing the phonemic make-up of the whole stimuli. For instance, the same number of nonword and real-word items started with the same onset. Furthermore, the nonwords were similar in length (as measured by the number of phonemes) to the real-word items.

The stimuli were produced in isolation by a male native speaker of Southern Standard British English in an anechoic recording chamber. The recording was digitized at a 48 kHz sampling rate and had 16-bit quantization.

3 Procedure

The study consisted of three stages: (1) participant screening, (2) a word learning experiment and (3) follow-up tests, structured as in Table 2. The word learning experiment featured three tasks (phoneme monitoring, stem completion and lexical decision),

Table 2. Example schedule for an 11:00 start.

Day	Session	Time	Task order		
1	1	11:00	(Screening) Onset-phoneme monitoring	Stem completion	
	2	13:30	Lexical decision	Phoneme monitoring	Stem completion
2	3	11:00	Lexical decision	Phoneme monitoring	Stem completion
	4	13:30	Lexical decision		
3	5	13:30	Lexical decision	(Follow-up)	
				Onset- phoneme monitoring	Vocabulary test

administered repeatedly in five sessions over three consecutive days. Sessions with all three tasks took approximately 30 minutes. The follow-up tests were conducted immediately after the final lexical decision task in Session 5. Apart from the follow-up vocabulary test, all tasks were conducted using DMDX (Forster and Forster, 2003). We describe each stage of the study and task below.

a Participant screening (onset-phoneme monitoring). Participant screening consisted of an auditory phoneme monitoring task using the novel words to be learned in the word learning experiment. For the participants who passed the screening, this task also formed part of the word learning experiment, in which they were exposed to the novel words for the first time. The novel words were divided into three groups: (1) those starting with /b/ or /v/, (2) /d/ or /m/ and (3) /s/ or /ʃ/. The participants heard three repetitions of each item in each group in two blocks. In one block, the participants monitored for one of the paired onset consonants (e.g. /b/); in the second block, they monitored for the other consonant (e.g. /v/). The participants thus monitored for each of the six onset consonants (/b/, /v/, /d/, /m/, /s/ and /ʃ/) in separate blocks. No feedback was provided except during a short practice session.

The cut-off for the screening test was a correct answer rate of 85% or above for all three consonant pairs (the successful participants' mean correct answer rates were much higher than 85% for all pairs, as shown below). Those who passed the screening test immediately proceeded to the stem completion task and continued with the word learning experiment.

b Word learning experiment (phoneme monitoring, stem completion and lexical decision). Phoneme monitoring: To be familiarized with the phonological form of novel words, participants auditorily monitored the words for various consonant phonemes other than /b/, /s/, /ʃ/ and /v/ (e.g. /f/, /g/, /p/, /t/) in five separate blocks. The four phonemes /b/, /s/, /ʃ/ and /v/ were excluded to encourage the participants to pay attention to the phonological form of the whole word (/b/, /s/, /ʃ/ and /v/ appeared in word-initial position only), and to prevent feedback from affecting Greek and Japanese participants' representations of the novel words starting with a member of difficult L2 contrasts. Each novel word was presented twice in each of the five blocks. At the beginning of each block, a target phoneme was specified on the computer screen: e.g. 'Listen for the *t* sound, as in team or meet each time you hear a word.' Both speed and accuracy were encouraged. Feedback was provided to help maintain attention and facilitate learning.

Stem completion: To facilitate learning and measure explicit recall of novel words, participants articulated the novel words in response to the word's initial fragment played as a cue. The word fragments were created by removing the final two segments from the novel words. For example, *-mp* was removed from *documemp* to create *docume-*. Each word fragment was presented once each in two blocks. At the end of each trial the participants heard the whole novel word regardless of their response. The responses were audio-recorded using a desktop microphone.

Lexical decision: An auditory lexical decision task was conducted to examine the emergence of lexical competition from novel words. In this task, participants indicated whether or not auditory stimuli were real English words as quickly and accurately as possible. The change in response to the base vs. control words in the course of the experiment were compared to assess the emergence of lexical competition from the novel words, and L1 homophone effects in the case of base words starting with /b/ or /v/ (Japanese) and /s/ or /ʃ/ (Greek). Thirty-nine real words and 39 nonwords were played once in each session. Approximately half of the 39 real words were the base words of the novel words to be learned; the rest were control words, which were unrelated to the novel words. All nonwords were different from, and unrelated to, the novel words. No feedback was given on the correctness of each answer.

c Follow-up tests (onset-phoneme monitoring, stem completion and vocabulary test). After the final lexical decision task in Session 5, the onset-phoneme monitoring task used for participant screening was repeated, to check if L2 participants could distinguish the difficult L2 test contrast as accurately as they did during the screening. This was followed by a short version of the stem completion task (each word fragment was presented only once) to assess how many novel words could be recalled on the last day. Additionally, a vocabulary test was administered to check off-line whether the participants knew the correct lexical status of the stimuli in the lexical decision task. In the vocabulary test, each stimulus was presented auditorily, and the participants responded whether they were (1) sure it was a real word, (2) sure it was not a real word or (3) unsure.

II Results

1 Onset-phoneme monitoring (participant screening and follow-up test)

Table 3 summarizes the percentage correct scores of the screening and follow-up onset-phoneme monitoring tasks obtained from the participants who passed the screening, along with their RTs (reaction times) to correct answers. A mixed design Analysis of Variance (ANOVA) was performed on square-root-transformed, percentage correct responses (Weisberg, 2005), with L1 as between-participants factor, and Contrast (/b/–/v/, /d/–/m/, and /s/–/ʃ/) and Time (first and last sessions) as within-participant factors. Data from the two members of each contrast were collapsed, as errors were found for both members with no clear pattern of asymmetry. The results revealed no significant effect of L1, the interaction between L1 and Contrast, or the interaction between L1,

Table 3. Successful participants' mean percentage correct scores and RTs to correct answers in the onset-phoneme monitoring task in the first (screening) and last (follow-up) sessions.

Session	Language group		Onset consonant pair		
			/b/ vs. /v/	/d/ vs. /m/	/s/ vs. /ʃ/
First (screening)	English	% correct	97 (4)	99 (2)	98 (4)
		RT (ms)	945 (183)	831 (139)	944 (235)
	Greek	% correct	97 (4)	98 (4)	96 (5)
		RT (ms)	887 (235)	831 (219)	1072 (389)
	Japanese	% correct	97 (4)	100 (0)	97 (2)
		RT (ms)	1016	886 (169)	1017 (182)
Last (follow-up)	English	% correct	97 (4)	99 (2)	95 (4)
		RT (ms)	629 (123)	563 (73)	683 (140)
	Greek	% correct	97 (2)	100 (1)	95 (4)
		RT (ms)	654 (282)	573 (186)	713 (250)
	Japanese	% correct	96 (5)	99 (1)	96 (3)
			672 (134)	587 (116)	671 (153)

Note. Standard deviations are given in brackets.

Contrast and Time ($F < 1$ in all cases). A comparable mixed design ANOVA was also performed on log-transformed RTs (Howell, 2010) to correct answers (measured from the stimulus onset), which revealed no effect of L1, or the interaction between L1, Contrast and Time ($F \leq 1$ in all cases). The interaction between L1 and Contrast almost reached the significance level ($p = 0.06$). Pairwise comparisons revealed a significant L1 x Contrast interaction for Greek and Japanese RTs ($p = 0.01$); compared to the Japanese participants, the Greek participants had shorter RTs for the /b/–/v/ contrast but longer RTs for the /s/–/ʃ/ contrast. However, there was no significant difference between English and Greek RTs or between English and Japanese RTs ($p > 0.1$). In short, the successful L2 participants, as groups, did not differ significantly from the L1 English participants in their ability to identify the members of the difficult L2 contrast in the novel words, either before or after the word learning experiment. (Individual differences within L2 groups will be discussed later, in relation to the results of the lexical decision task.)

2 *Stem completion*

Responses in the stem completion task were coded as either correct or incorrect, depending on whether the missing offset was correctly recalled and produced. As we were not concerned with all aspects of L2 phonology, the following errors specific to L2 groups were overlooked: realizations of a vowel phoneme as an adjacent vowel in the vowel space (e.g. /i/ for /ɪ/), /l/–/r/ confusion (Japanese participants only), and misplacement of lexical stress.

Figure 1 plots the three language groups' percentage correct response rates in the follow-up stem completion task, conducted immediately after the final lexical decision

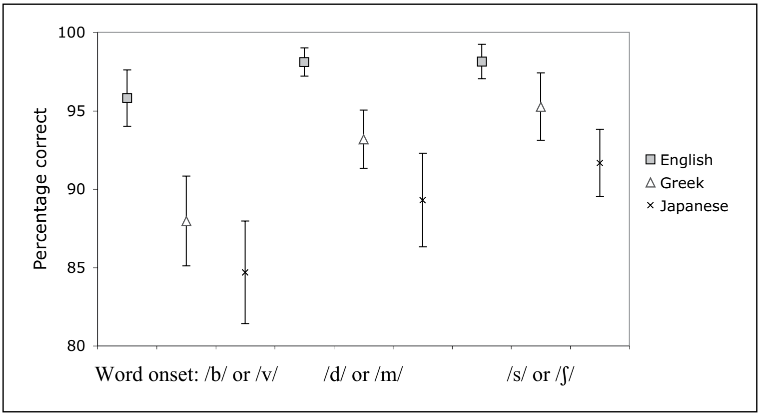

Figure 1. The three language groups' mean percentage correct responses in the follow-up stem completion task. Error bars represent the standard error of the mean.

task. On average, the ending of over 80% of novel words were correctly remembered by all groups, indicating successful learning.

A mixed design ANOVA was run on square-root-transformed percentage correct response rates, with L1 as between-participants factor, and Word Onset (/b/ or /v/, /d/ or /m/, and /s/ or /ʃ/) and Session as within-participant factors. The effect of L1 was significant: $F(2,50) = 11.9$, $p < .001$, $\eta_p^2 = .32$.[3] According to a post-hoc Tamhane test, the L1 English group was significantly better at remembering the novel words than both the Greeks and Japanese ($p = .023$, $p < .001$). The Greeks and Japanese did not differ significantly from each other ($p = .15$). The observed difference between the L1 English vs. L1 Greek and Japanese participants is likely to have arisen from the participants' L1 background, considering that the participants' age and general level of education were comparable between the three groups (see the Participants section). The effect of Session was also significant, reflecting better recalls in later sessions: $F(3,150) = 255$, $p < .001$, $\eta_p^2 = .84$. Finally, the effect of Word Onset was significant: $F(2,100) = 15.0$, $p < .001$, $\eta_p^2 = .23$. A post-hoc Sidak test indicated that all three language groups remembered the novel words starting with /d/, /m/, /s/ or /ʃ/ better than those starting with /b/ or /v/. We do not have ready explanations for this. There was no significant interaction between the above factors at $\alpha = .05$.

3 Lexical decision

In the lexical decision task, participants responded to two kinds of real-word stimuli: (1) base words, from which novel words were derived, and (2) control words, which were unrelated to the novel words (see Table 1 above). As the stimuli in the lexical decision task were identical across sessions except in presentation order, a practice effect should produce a general decrease in RT and/or error rates in later sessions. At the same time, the emergence of lexical competition from the newly learned words (novel words) should counteract the practice effect. In Lindsay and Gaskell (2013) this led to a relatively small decrease in RT to base words in later sessions, compared to control words.

In the present study lexical competition from novel words starting with /d/ or /m/ (e.g. *documemp*) for associated base words (e.g. *document*; 'd/m base words') should emerge in the course of the experiment, regardless of L1 background. Therefore, all three language groups are expected to exhibit a smaller decrease in RT and/or error rates across sessions for the d/m base words than for the control words. If L1 homophone effects are also present, Greek participants should additionally exhibit a smaller decrease in RT and/or error rates for base words starting with /s/ or /ʃ/ (e.g. *sentiment*; 's/sh base words') compared to the control words. Japanese participants should exhibit a smaller decrease in RT and/or error rates for base words starting with /b/ or /v/ (e.g. *benefit*; 'b/v base words') compared to the control words.

To test these predictions, we first analysed RTs to correct responses to the control vs. three types of base words. We only included in the analysis responses from each participant to words they reported to know in the follow-up vocabulary test (all base and control words for L1 English; 94% for Greek; 93% for Japanese). Additionally, RTs shorter than 300 ms and longer than 2000 ms from the stimulus onset were excluded from the data as outliers; this accounted for less than 1% of the data. Figure 2 gives each language group's mean RT to each type of stimuli (from the stimulus offset) in the first and last lexical decision tasks. As the figure shows, RTs were shorter in the last than in the first session for all word types and language groups, suggesting a practice effect. Importantly, the decrease in RT is smaller for some types of base words than the control words, suggesting the emergence of lexical competition from some novel words.

To statistically compare the change in RT for different word types, a mixed design ANOVA was run on RTs (from the stimulus offset) to correct answers with Word Type (b/v base words, d/m base words, s/sh base words, and control words) and Session (from 2 to 5) as within-participant factors, and L1 as between-participants factor.[4] The effect of L1 was significant: $F(2,51) = 7.78$, $p = .001$, $\eta_p^2 = .23$. According to a post-hoc Tamhane test, the L1 English group made lexical decisions significantly faster than the Greeks and Japanese ($p = .021$, $p < .001$, respectively). The L2 groups did not differ significantly from each other ($p = .90$). As with the stem completion task, the observed difference is likely to be due to the Greek and Japanese participants being L2 speakers of English, given that the three groups were comparable in age and general level of education (see the Participants section). The effect of Session was also significant: $F(3,5) = 48.8$, $p < .001$, $\eta_p^2 = .49$. According to a post-hoc Sidak test, RT was significantly longer in Sessions 2 and 3 than in Sessions 4 and 5 ($p < .001$), indicating a practice effect. Finally, the interaction between Session and Word Type was significant: $F(8,392) = 7.68$, $p = .015$, $\eta_p^2 = .046$. According to a post-hoc Sidak test run on difference scores between RT in Session 2 and each of the later sessions, the overall decrease in RT was significantly smaller for the d/m base words than for the control words ($p = .004$), while neither the b/v or s/sh base words differed significantly from the control words ($p = 1$, $p = .20$). Crucially, the interaction between L1, Word Type and Session was not significant, providing no evidence for lexical competition arising from language-specific L1 homophone effects: $F(15,392) < 1$. In sum, clear evidence for lexical competition was present in RT for the d/m base words only, regardless of L1 background.

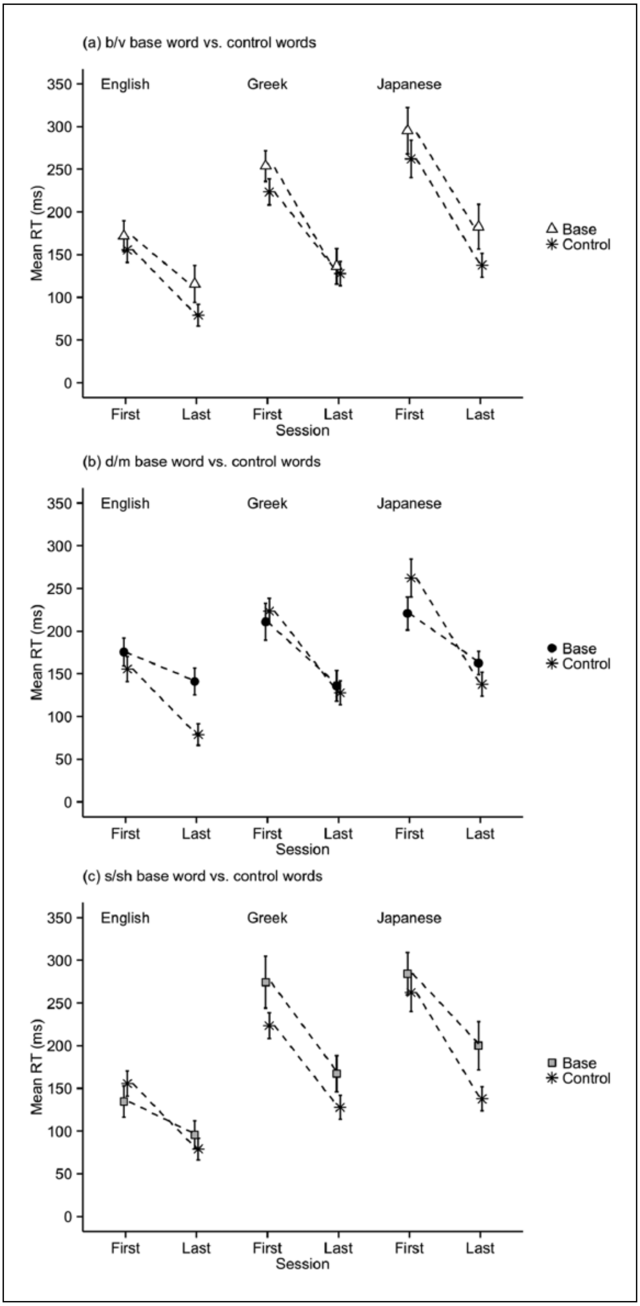

Figure 2. Mean RTs to correct responses in the lexical decision tasks in Session 2 vs. Session 5.
Notes. From the top, each figure compares (a) b/v base words (e.g. *benefit*), (b) m/d base words (e.g. *document*) and (c) s/sh base words (e.g. *sentiment*), with control words. Error bars represent the standard error of the mean.

Though error rates were generally low ($M = 6\%$), they were also examined to check whether 1) a shift in the speed-accuracy trade-off (e.g. Meyer et al., 1988) can explain the smaller decrease in RT for the d/m base words than for the control words, and 2) evidence for L1 homophone effects can be found in the shift in error rates across sessions. A mixed design ANOVA run on square-root-transformed error rates (within-participant factors: Word Type and Session; between-participant factor: L1) indicated no significant interaction between Word Type and Session, or Word Type, Session and L1 at $\alpha = .05$, corroborating the above interpretation of the results that lexical competition from novel words was present for the d/m base words only.

The group results of the lexical decision task thus suggest that L1 homophone effects are absent in L2 listeners who can discriminate difficult L2 contrasts reliably, consistent with the view that the effects are contingent on the L2 listener's lack of ability to discriminate the contrast. The analysis presented so far, however, only constitutes negative evidence for the contingency. In search of positive evidence, we examined the relationship between individual participants' performance on the onset-phoneme monitoring task and the change in their performance in the lexical decision task over the course of the experiment. We observed earlier that the error rates for different contrasts in the onset-phoneme monitoring task did not differ significantly between L1 and L2 groups. However, as can be seen in Figure 3, the Greek participants were slightly more variable in their correct answer rates for /s/ vs. /ʃ/, and the Japanese participants for /b/ vs. /v/, than the other two language groups. In other words, the Greek and Japanese participants tended to vary more in their abilities to distinguish the difficult L2 contrasts than did the other language groups. If L1 homophone effects are contingent on the L2 listener's lack of ability to distinguish the difficult L2 contrast reliably, some of our L2 participants might have been affected by the effects to a degree, even though the effects were not observable at the group level.

To explore the above possibility, for each language group and each L2-specific contrast (/b/–/v/ and /s/–/ʃ/), Spearman correlation tests were run on individual participants' error rates in the onset-phoneme monitoring task (averaged across the screening and follow-up tests) and the differences in their mean RTs (to correct answers) as well as error rates, between the first and last lexical decision tasks for associated base words.[5] A significant negative correlation was found between the Greek participants' error rates for /s/ vs. /ʃ/ in the onset-phoneme monitoring task and the difference in their error rates for s/sh base words in the first vs. last lexical decision tasks: $rs(16) = -0.53$, $p = 0.02$. Similarly, a significant negative correlation was found between the Japanese participants' correct percentage scores for /b/ vs. /v/ in the onset-phoneme monitoring task and the difference in their error rates for b/v base words in the first vs. last lexical decision task: $rs(16) = -0.68$, $p = 0.002$. Thus, the more errors the Greek and Japanese participants made with the difficult L2 contrast in the onset-phoneme monitoring task, the greater number of errors the participants made with the associated base words in the last lexical decision task, relative to the first lexical decision task. These results suggest that the Greek and Japanese participants who could not discriminate the difficult L2 contrast as reliably as others did experience lexical competition from novel words starting with a member of the difficult contrast, consistent with the idea that L1 homophone effects are contingent on L2 listeners' lack of abilities to discriminate difficult L2 contrasts. The

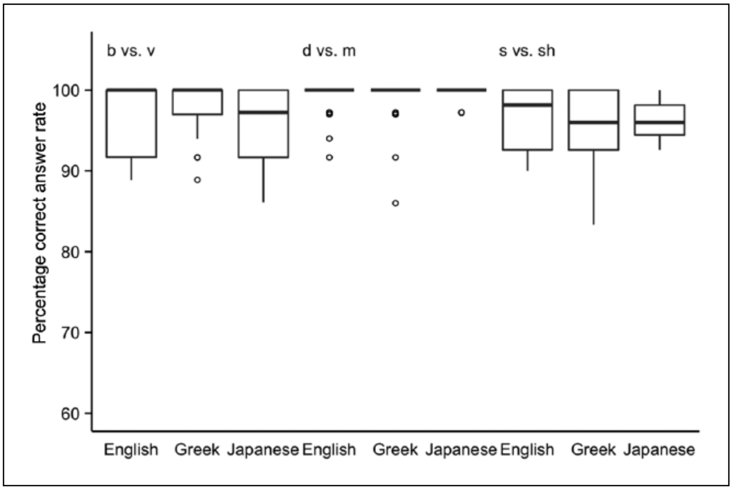

Figure 3. Distributions of percentage correct answer rates in the onset-phoneme monitoring task plotted for each contrast and language.
Notes. Results from the screening and follow-up tests are collapsed). Each box represents the 25th–75th percentile of the distribution of correct answer rates. Whiskers represent the entire distribution, excluding outliers (represented as circles). Horizontal lines inside the boxes represent median values.

observed correlations are unlikely to have arisen from a shift in the speed-accuracy trade-off in the lexical decision task; for neither language group was there a significant correlation between the error rates for the difficult L2 contrast in the onset-phoneme monitoring task and the magnitudes of decrease in RT for the associated base words in the lexical decision task (Greek, /s/ vs. /ʃ/: $rs(16) = -0.02$, $p = 0.95$; Japanese, /b/ vs. /v/: $rs(16) = 0.28$, $p = 0.25$).

Significant negative correlations were also found between error rates for /b/ vs. /v/ in the onset-phoneme monitoring task and the difference in the L1 English and Greek listeners' RTs for b/v words in the first vs. last lexical decision tasks ($rs(16) = -0.52$, $p = 0.03$; $rs(16) = -0.63$, $p = 0.005$, respectively). These results suggest that spurious activation of words containing a member of a perceptually similar phonemic contrast in lexical access may not be limited to L2 listeners whose L1 lacks the contrast. The results are not surprising, considering reports of gradient lexical activation induced by nonword primes in L1, reflecting the degrees of phonetic/phonological similarity of the nonword primes to the activated words (Andruski et al. 1994; Connine et al. 1993). No other correlations were significant at $\alpha = .05$.

IV Conclusion

Few have demonstrated an absence of L1 homophone effects (simultaneous activations of L2 words differing by difficult L2 contrasts that map to a single L1 phoneme) in L2 listeners who can discriminate relevant difficult L2 contrasts with native-like accuracy, even though many researchers assume that inadequate phonetic processing abilities for difficult L2 phonemic contrasts are a prerequisite to L1 homophone effects (e.g. Broersma, 2012; Cutler et al., 2006; Darcy et al., 2012; Weber and Cutler, 2004). Furthermore, L1 homophone effects observed for orthographic stimuli (Ota et al., 2009) suggest that L1 homophone effects can manifest themselves without the direct involvement of phonetic processing, raising two possibilities: (1) L1 homophone effects can occur independently of L2 listeners' abilities to distinguish difficult L2 contrasts, or (2) the effects can occur under an indirect influence of L2 listeners' lack of abilities to discriminate difficult L2 contrasts reliably.

In order to distinguish the two possibilities, we conducted a word learning experiment that examined whether or not L1 homophone effects can be observed in spoken-word recognition by L2 participants who can perceptually discriminate a difficult L2 contrast with native-like accuracy. We note that most of our L2 participants were clearly not native equivalents in all aspects of English proficiency, consistent with their self-reports, although the L2 groups did not differ significantly from the L1 English group in their abilities to discriminate the members of the relevant L2 contrasts. As we have seen, the L2 participants could not correctly remember as many novel words as the L1 English participants in the stem completion task, and were slower than the L1 English participants in their overall responses in the lexical decision task.

Our results suggest that L1 homophone effects in spoken-word recognition are indeed contingent on L2 listeners' inabilities to discriminate difficult L2 contrasts. We found no group-level evidence of language-specific L1 homophone effects in a word learning experiment for our L2 participants. This is despite our success in inducing, for both native and L2 participants, lexical competition from novel words that did not start with a member of difficult L2 contrasts (e.g. *documemp, madonnid*). The lexical competition observed for associated base words (e.g. *document, Madonna*) indicates that our participants consolidated in their mental lexicon the phonological forms of the novel competitor words (i.e. *documemp, madonnid*); (Gaskell and Dumay 2003; Lindsay and Gaskell 2013). One would therefore expect other novel words to have also been consolidated into the participants' lexicon, ready to participate in lexical competition under L1 homophone effects. Specifically, novel words beginning with /s/ or /ʃ/ (e.g. *sepon, shentimemp*) would have competed with associated base words (e.g. *shepherd, sentiment*) for the Greeks, and novel words beginning with /b/ or /v/ (e.g. *bictift, venefop*) would have competed with associated base words (e.g. *victim, benefit*) for the Japanese. No such evidence was found in the group results of the lexical decision task. At the same time, analysis within each language group revealed that the more errors the L2 participants made with the difficult L2 contrast in the onset-phoneme monitoring task, the greater number of errors they made with the base words containing a member of that contrast in the final lexical decision task, as compared to the first lexical decision task. These results suggest that the strength of L1 homophone effects reflects the L2 participants' sensitivity to the acoustic difference between the members of the difficult L2 contrast.

In conclusion, our results are consistent with the view that L1 homophone effects in spoken-word recognition, directly or indirectly, stem from the L2 listeners' inabilities to discriminate difficult L2 contrasts, and inconsistent with the view that L1 homophone effects can occur purely due to a mismatch in L1 and L2 phonemic inventories, independent of the learners' ability to discriminate the contrast auditorily. In light of previous findings, we interpret our results to suggest that the lack of ability to perceptually discriminate the relevant L2 contrast is a necessary, not sufficient, condition for L1 homophone effects. In this experiment the participants learned novel words from auditory stimuli only, which yielded a straightforward negative relationship between the participant's ability to discriminate the difficult L2 contrasts and the strength of L1 homophone effects. As we touched on in the introduction, this relationship may become complex depending on the ways in which L2 learners acquire novel words. For example, Escudero et al. (2008) report that the use of orthographic information in a word learning experiment produced asymmetric L1 homophone effects of the kind observed by Weber and Cutler (2004) and Cutler et al. (2006), where the effect is limited to words that contain one (and not the other) member of a difficult L2 contrast.

Needless to say, a full understanding of the relationship between L2 listeners' phonetic processing abilities and L1 homophone effects would require more studies with various L2 contrasts, populations and tasks. It is possible, for example, that L1 homophone effects persist in word recall by L2 learners who do not exhibit the effects in spoken-word recognition, given reports that errors driven by phonological similarity mainly arise during memory retrieval and not during input encoding (e.g. Baddeley, 1968). For now, though, the assumption that L1 homophone effects are contingent on the L2 listener's lack of abilities to distinguish the relevant L2 contrast reliably appears to be justified.

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Declaration of Conflicting Interest

The authors declare that there is no conflict of interest.

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Notes

1. The questionnaire described 'advanced' level of English proficiency as 'fluent but not at a native level', and 'intermediate' level as 'not fluent but good enough to get by at the university'.
2. All word-initial /s/ and /ʃ/ preceded a vowel other than high front vowels, because /s/ and /ʃ/ are not contrasted before the high front vowel in Japanese (and not just in Greek).
3. Throughout the article, the degrees of freedom in mixed design ANOVAs were corrected using the Huynh–Feldt correction method, where the sphericity assumption was not met.
4. We also split the b/v and s/sh base words into four groups depending on the onset consonant and conducted statistical analysis. The conclusions that can be drawn from the additional analysis were the same.
5. RTs in the onset-monitoring task were not used, because individual participants' RTs for the three contrasts (i.e. /d/–/m/, /s/–/ʃ/ and /b/–/v/) significantly correlated with each

other ($r > .74$), indicating that RTs cannot be straightforwardly used as a measure of individual differences in sensitivity to acoustic differences between the members of difficult L2 contrasts.

References

Andruski JE, Blumstein SE, and Burton M (1994) The effect of subphonetic differences on lexical access. *Cognition* 52: 163–87.

Aoyama K, Flege JE, Guion SG, Akahane-Yamada R, and Yamada T (2004) Perceived phonetic dissimilarity and L2 speech learning: the case of Japanese /r/ and English /l/ and /r/. *Journal of Phonetics* 32: 233–50.

Arvaniti A (2007) Greek phonetics: The state of the art. *Journal of Greek Linguistics* 8: 97–208.

Baddeley AD (1968) How does acoustic similarity influence short-term memory? *The Quarterly Journal of Experimental Psychology* 20: 249–64.

Best CT (1991) The emergence of native-language phonological influences in infants: A perceptual assimilation model. *Haskins Laboratories Status Report on Speech Research* SR-107/108: 1–30.

Best CT and Strange W (1992) Effects of phonological and phonetic factors on cross-language perception of approximants. *Journal of Phonetics* 20: 305–30.

Best CT and Tyler MD (2007) Nonnative and second-language speech perception: Commonalities and complementarities. In: Bohn O-S and Munro MJ (eds) *Language experience in second language speech learning: In honor of James Emil Flege*. Amsterdam: John Benjamins, 13–34.

Broersma M (2002) Comprehension of non-native speech: Inaccurate phoneme processing and activation of lexical competitors. In: Hansen JHL and Pellom BL (eds) *Seventh International Conference on Spoken Language Processing*. Denver, CO: Center for Spoken Language Research, 261–64.

Broersma M (2012) Increased lexical activation and reduced competition in second-language listening. *Language and Cognitive Processes* 27: 1205–24.

Brown C (2000) Speech perception and phonological acquisition. In: Archibald J (ed.) *Second language acquisition and linguistic theory*. Malden, MA: Blackwell, 4–63.

Connine CM, Blasko DG, and Titone D (1993) Do the beginnings of spoken words have a special status in auditory word recognition? *Journal of Memory and Language* 32: 193–210.

Cutler A, Smits R, and Cooper N (2005) Vowel perception: Effects of non-native language vs. non-native dialect. *Speech Communication* 47: 32–42.

Cutler A, Weber A, and Otake T (2006) Asymmetric mapping from phonetic to lexical representations in second-language listening. *Journal of Phonetics* 34: 269–84.

Darcy I, Dekydtspotter L, Sprouse RA, Glover J, Kaden C, McGuire M, and Scott JHG (2012) Direct mapping of acoustics to phonology: On the lexical encoding of front rounded vowels in L1 English– L2 French acquisition. *Second Language Research* 28: 5–40.

Duyck W, Diependaele K, Drieghe D, and Brysbaert M (2004) The size of the cross-lingual masked phonological priming effect does not depend on second language proficiency. *Experimental Psychology* 51: 116–24.

Escudero P (2009) The linguistic perception of similar L2 sounds. In: Boersma P and Hamann S (eds) *Phonology in perception*. Berlin: Mouton de Gruyter, 151–90.

Escudero P and Boersma P (2004) Bridging the gap between L2 speech perception research and phonological theory. *Studies in Second Language Acquisition* 26: 551–85.

Escudero P, Hayes-Harb R, and Mitterer H (2008) Novel second-language words and asymmetric lexical access. *Journal of Phonetics* 36: 345–60.

Forster KI and Forster JC (2003) DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods, Instruments, and Computers* 35: 116–24.

Gaskell MG and Dumay N (2003) Lexical competition and the acquisition of novel words. *Cognition* 89: 105–32.

Howell DC (2009) *Statistical methods for psychology*. Belmont, CA: Wadsworth, Cengage Learning.

Ju M and Luce PA (2004) Falling on sensitive ears: Constraints on bilingual lexical activation. *Psychological Science* 15: 314–18.

Lindsay S and Gaskell MG (2013) Lexical integration of novel words without sleep. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 39: 608–22.

Meyer DE, Irwin DE, Osman AM, and Kounios J (1988) The dynamics of cognition and action: Mental processes inferred from speed-accuracy decomposition. *Psychological Review* 95: 183–237.

Norris D, McQueen JM, and Cutler A (1995) Competition and segmentation in spoken-word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 21: 1209–28.

Ota M, Hartsuiker RJ, and Haywood SL (2009) The KEY to the ROCK: Near-homophony in nonnative visual word recognition. *Cognition* 111: 263–69.

Pallier C, Colomé A, and Sebastián-Gallés N (2001) The influence of native-language phonology on lexical access: Exemplar-based versus abstract lexical entries. *Psychological Science* 12: 445–49.

Vance TJ (2008) *The sounds of Japanese*. Cambridge: Cambridge University Press.

Weber A and Cutler A (2004) Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language* 50: 1–25.

Weisberg S (2005) *Applied linear regression*. New York: John Wiley and Sons.

Zhou H, Chen B, Yang M, and Dunlap S (2010) Language nonselective access to phonological representations: Evidence from Chinese–English bilinguals. *The Quarterly Journal of Experimental Psychology* 63: 2051–66.

Appendix 1. Participant details.

Group	Age	Gender	Age of arrival in English-speaking country	Length of residence in English-speaking country	Self-reported English proficiency	Proficiency in foreign language
English	20	Male	n/a	from birth	native speaker	n/a
English	22	Male	n/a	from birth	native speaker	n/a
English	23	Male	n/a	from birth	native speaker	French (advanced)
English	27	Male	n/a	from birth	native speaker	Icelandic (intermediate)
English	31	Male	n/a	from birth	native speaker	n/a
English	31	Male	n/a	from birth	native speaker	French (advanced)
English	42	Male	n/a	from birth	native speaker	French (advanced), German (advanced)
English	20	Female	n/a	from birth	native speaker	n/a
English	21	Female	n/a	from birth	native speaker	n/a
English	23	Female	n/a	from birth	native speaker	n/a
English	24	Female	n/a	from birth	native speaker	n/a
English	25	Female	n/a	from birth	native speaker	French (intermediate)
English	25	Female	n/a	from birth	native speaker	n/a
English	25	Female	n/a	from birth	native speaker	n/a
English	27	Female	n/a	from birth	native speaker	n/a
English	27	Female	n/a	from birth	native speaker	n/a
English	30	Female	n/a	from birth	native speaker	German (advanced)
English	39	Female	n/a	from birth	native speaker	French (advanced), German (advanced)
Greek	24	Male	23	1 year	advanced	German (advanced)
Greek	26	Male	21	5 years	advanced	French (advanced), Farsi (advanced)

(Continued)

Appendix 1. (Continued)

Group	Age	Gender	Age of arrival in English-speaking country	Length of residence in English-speaking country	Self-reported English proficiency	Proficiency in foreign language
Greek	26	Male	24	2 years	advanced	French (advanced)
Greek	26	Male	21	5 years	near native	Romanian (advanced)
Greek	27	Male	26	11 months	advanced	Spanish (advanced)
Greek	27	Male	25	2 years	advanced	n/a
Greek	29	Male	28	1 year 4 months	advanced	German (advanced)
Greek	23	Female	21	1 year 10 months	advanced	French (advanced)
Greek	24	Female	23	1 year 1 month	near native	Spanish (advanced)
Greek	24	Female	23	9 months	intermediate	German (advanced)
Greek	25	Female	24	11 months	advanced	French (intermediate)
Greek	25	Female	24	10 months	advanced	German (advanced)
Greek	25	Female	24	1 year	advanced	French (intermediate)
Greek	26	Female	24	2 years	advanced	Spanish (intermediate)
Greek	27	Female	25	2 years	advanced	German (intermediate)
Greek	27	Female	26	1 year	near native	German (intermediate)
Greek	28	Female	23	5 years	advanced	German (intermediate), Spanish (intermediate)
Greek	29	Female	24	5 years	advanced	French (advanced), Italian (advanced)
Japanese	22	Male	19	3 years	near native	n/a
Japanese	25	Male	19	6 years	near native	n/a
Japanese	40	Male	37	3 years	advanced	n/a
Japanese	19	Female	18	1 year	intermediate	n/a
Japanese	19	Female	18	1 year	intermediate	n/a

Appendix 1. (Continued)

Group	Age	Gender	Age of arrival in English-speaking country	Length of residence in English-speaking country	Self-reported English proficiency	Proficiency in foreign language
Japanese	21	Female	19	2 years months	advanced	n/a
Japanese	21	Female	16	5 years	advanced	n/a
Japanese	23	Female	22	1 year 3 months	advanced	n/a
Japanese	27	Female	20	7 years	advanced	n/a
Japanese	27	Female	26	7 months	intermediate	n/a
Japanese	27	Female	26	1 year 4 months	advanced	n/a
Japanese	28	Female	27	1 year	intermediate	n/a
Japanese	29	Female	24	4 years 10 months	intermediate	n/a
Japanese	29	Female	25	3 years 10 months	advanced	n/a
Japanese	29	Female	17	12 years	advanced	n/a
Japanese	30	Female	25	5 years	advanced	n/a
Japanese	37	Female	33	4 years	advanced	n/a
Japanese	39	Female	38	1 year	intermediate	n/a

Appendix 2. List of novel words.

Onset	Novel word		Base word
/b/	banitef	/ˈbæn.ɪ.təf/	*vanity*
	berdimp	/ˈbɜː.dɪmp/	*verdict*
	berticad	/ˈbɜː.tɪ.kæd/	*vertical*
	bictift	/ˈbɪk.tɪft/	*victim*
	binigik	/ˈbɪn.ɪ.gɪk/	*vinegar*
	bolcaynide	/bɒlˈkeɪ.naɪd/	*volcano*
/d/	daffodak	/ˈdæf.ədək/	*daffodil*
	delicom	/ˈdel.ɪ.kɒm/	*delicate*
	demarft	/dɪˈmɑːft/	*demand*
	deputot	/ˈdep.jʊ.tɒt/	*deputy*
	diamoft	/ˈdaɪə.məft/	*diamond*
	documemp	/ˈdɒk.jʊ.məmp/	*document*
/m/	madonid	/məˈdɒ.nɪd/	*Madonna*
	magnenk	/ˈmæg.nəŋk/	*magnet*
	maintope	/meɪnˈtəʊp/	*maintain*
	minerick	/ˈmɪn.ərɪk/	*mineral*
	minimuff	/ˈmɪn.ɪ.mɒf/	*minimum*
	monitig	/ˈmɒn.ɪ.tɪg/	*monitor*
/s/	sandelayff	/ˌsæn.dəˈleɪf/	*chandelier*
	serarnt	/səˈrɑːnt/	*charade*
	selond	/səˈlɒnd/	*shallot*
	samret	/ˈsæm.rɛt/	*shamrock*
	seltid	/ˈsel.tɪd/	*shelter*
	sepon	/ˈsep.ɒn/	*shepherd*
/ʃ/	shirtifiked	/ʃəˈtɪf.ɪ.kɛd/	*certificate*
	shardoot	/ʃɑːˈduːt/	*sardine*
	shentimemp	/ˈʃen.tɪ.məmp/	*sentiment*
	sheparog	/ˈʃep.ər.ɔg/	*separate*
	shuffokyne	/ˈʃʌf.ə.kaɪn/	*suffocate*
	shepornk	/ʃəˈpɔːŋk/	*support*
/v/	vadmintig	/ˈvæd.mɪn.tɪg/	*badminton*
	vananid	/vəˈnɑː.nɪd/	*banana*
	venifup	/ˈven.ɪ.fəp/	*benefit*
	vikeenoot	/vɪˈkiː.nuːt/	*bikini*
	voomereet	/ˈvuː.mə.riːt/	*boomerang*
	voykeck	/ˈvɔɪ.kɛk/	*boycott*

Appendix 3. List of control words.

alcohol
etiquette
frequent
garlic
hurricane
helicopter
improve
yoghurt
command
compact
capital
nicotine
October
penguin
perfect
picnic
potato
tomato
tenant
terminate
weapon

Appendix 4. List of nonwords.

apriken /ˈeɪ.prɪkən/ (*apricot*)
bargum /ˈbɑː.gəm/ (*bargain*)
biscal /ˈbɪs.kəl/ (*biscuit*)
brambooce /ˈbræm.bu:s/ (*bramble*)
dictuke /dɪkˈtu:k/ (*dictate*)
decadumph /ˈdek.ə.dəmf/ (*decadent*)
dolpheg /ˈdɒl.fɛg/ (*dolphin*)
elevaytig /ˈel.ɪ.veɪ.tɪg/ (*elevator*)
fountum /ˈfaʊn.təm/ (*fountain*)
grimin /ˈgrɪ.mɪn/ (*grimace*)
huzbupt /ˈhʌz.bəpt/ (*husband*)
hungrone /ˈhʌŋ.grəʊn/ (*hungry*)
imadgep /ɪˈmædʒ.ɛp/ (*imagine*)
utensont /juːˈten.sɒnt/ (*utensil*)
cockpun /ˈkɒk.pən/ (*cockpit*)
cardigite /ˈkɑː.dɪ.gaɪt/ (*cardigan*)
kidnand /ˈkɪd.nænd/ (*kidnap*)
milityne /ˈmɪl.ɪ.taɪn/ (*military*)
mountug /ˈmaʊn.təg/ (*mountain*)
medityne /ˈmed.ɪ.taɪn/ (*meditate*)
napcum /ˈnæp.kəm/ (*napkin*)
ornamunk /ˈɔː.nə.məŋk/ (*ornament*)
pyramon /ˈpɪr.ə.mɒn/ (*pyramid*)
pelicut /ˈpel.ɪ.kət/ (*pelican*)
peacond /ˈpiː.kɒnd/ (*peakcock*)
parsneg /ˈpɑː.snɛg/ (*parsnip*)
segmumph /ˈseg.məmf/ (*segment*)
slowgiss /ˈsləʊ.gɪs/ (*slogan*)
spazet /ˈspæz.ɛt/ (*spasm*)
chaperaygue /ˈʃæp.ə.reɪg/ (*chaperon*)
shadyfe /ˈʃæd.aɪf/ (*shadow*)
shakig /ˈʃæk.ɪg/ (*shackle*)
targup /ˈtɑː.gəp/ (*target*)
tortope /ˈtɔː.təʊp/ (*tortoise*)
trampolig /ˈtræm.pəl.ɪg/ (*trampoline*)
vaycump /ˈveɪ.kəmp/ (*vacant*)
vizimph /ˈvɪz.ɪmf/ (*visit*)
vouchet /ˈvaʊ.tʃɛt/ (*voucher*)
windaym /ˈwɪn.deɪm/ (*window*)

Note. Original words, from which nonwords were created, are given in brackets.