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Cross-script phonological priming for Japanese-English bilinguals: Evidence for integrated phonological representations

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Previous masked phonological priming studies with bilinguals whose languages are written in the same script (e.g., Dutch-French bilinguals) strongly suggest that phonological representations for the two languages are integrated, based on the fact that phonological activation created by reading a word in one language facilitates word identification in the other language. The present research examined whether the same is true for different-script bilinguals (Japanese-English bilinguals). In this study, participants made lexical decisions to English targets (e.g., GUIDE) that were primed by three types of masked Japanese primes: cognate translation equivalents (e.g., ガイド, /gaido/, *guide*), phonologically similar but conceptually unrelated words (e.g., サイド, /saido/, *side*), and phonologically and conceptually unrelated words (e.g., コール, /koRru/, *call*). There were significant priming effects for cognate translation primes (94 ms) and phonologically similar primes (30 ms). Whereas the cognate translation priming effect was modulated by target frequency and L2 proficiency, the phonological priming effect was not. Our results suggest that phonological representations for different languages are integrated even if the languages in question use different scripts. The role of phonological activation in bilingual word recognition is discussed.

Keywords: Bilingual visual word recognition; Masked phonological priming; Masked translation priming; Lexical decision.

The question of how bilinguals process and represent multiple languages has been of interest to language researchers for many decades (e.g., Kroll & Curley, 1988; Kroll & Stewart, 1994; Potter, So, Von Eckardt, & Feldman, 1984; Weinreich, 1953). Traditionally, bilinguals were assumed to have two completely separate lexicons, with the words in the two lexicons linked to one another through direct associations between translation equivalents or through shared conceptual representations.

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(Weinreich, 1953). This assumption of separate lexicons generally led to a language-selective view of bilingual lexical memory that was incorporated into a number of models, including the word association model (e.g., Kroll & Curley, 1988), the concept mediation model (e.g., Kroll & Curley, 1988; Potter et al., 1984), and the revised hierarchical model (e.g., Kroll & Stewart, 1994). One implication of a language-selective view is that reading a word in one language activates orthographic and phonological representations of that language but does not typically activate orthographic and/or phonological representations of the other language.

In contrast, recent models of bilingual lexical memory have begun to incorporate an alternative, nonselective view of the bilingual lexicon in order to accommodate the growing empirical evidence that lexical activation is not strictly limited to representations specific to the language being read (see Dijkstra, 2005, for recent review). In the distributed lexical/conceptual feature model (Kroll & De Groot, 1997), for example, lexical features and conceptual features are stored in a distributed fashion and shared between languages, with these representations mediated by language-specific lemmas containing syntactic information of each language. A localist-connectionist model of bilingual word recognition, the Bilingual Interactive Activation Model+ (BIA+) model (Dijkstra & Van Heuven, 2002), also assumes that orthographic, phonological, and semantic representations are activated language nonselectively. The BIA+ model further assumes that lexical representations are stored in a unified lexicon and that the lexical activation of a word in one language can be affected by lexical competition among words from both languages. According to these language nonselective views of bilingual lexical representation, when a word is read in either language, orthographic, phonological, and conceptual representations are activated for both languages, which affects the processing leading to the identification of the word.

One line of evidence supporting the idea that bilingual word recognition is language nonselective comes from research using the cross-language masked phonological priming paradigm (e.g., Brysbaert, Van Dyck, & Van de Poel, 1999; Duyck, Diependaele, Drieghe, & Brysbaert, 2004; see Brysbaert, 2003, for a review). For example, in Brysbaert et al.'s (1999) Experiment 1, a French target (e.g., *oui*) was primed by a phonologically similar Dutch word (an inter-lingual homophone: e.g., *wie*) or by a phonologically unrelated Dutch word (an orthographic control: e.g., *jij*). For Dutch-French bilinguals, perceptual identification performance was superior when targets were primed by inter-lingual homophones (30%) than when they were primed by orthographic controls (23%). Very similar results were reported by Duyck et al. (2004) using the same paradigm with two groups of Dutch-French bilinguals: highly proficient (simultaneous) bilinguals and less proficient (late) bilinguals. In addition, Duyck et al. also found that the phonological priming effects were statistically equivalent for the two groups of bilinguals (7.4% and 6.9%, respectively) despite their differing levels of L2 proficiency. The existence of a cross-language masked homophone priming effect implies that (1) phonological activation occurs automatically, and (2) phonological representations in the two languages are integrated, allowing phonological activation in the first language to facilitate word identification in the second language, much like the way that phonologically similar primes facilitate responses to targets in monolingual masked priming experiments (e.g., Ferrand & Grainger, 1993, 1994; Perfetti, Bell, & Delaney, 1988; Pollatsek, Perea, & Carreiras, 2005).

PRIMING EFFECTS FOR BILINGUALS WITH SAME- AND DIFFERENT-SCRIPT LANGUAGES

The language nonselective view of bilingual lexical memory, including the assumption that phonological representations are integrated for the two languages, is supported by Duyck et al.'s (2004) results as well as the results from many other studies with bilinguals whose languages have a common script (e.g., Brysbaert et al., 1999; De Groot & Nas, 1991; Dijkstra, Grainger, & Van Heuven, 1999; Duñabeitia, Perea, & Carreiras, 2010; Lemhofer & Dijkstra, 2004). However, it remains unclear whether this conclusion can be extended to situations in which the bilingual's languages do not share a script.

If two scripts do not share orthography, a logical assumption would be that different-script bilinguals must possess functionally separate structures for representing orthographic information in their two languages. The assumption of separate lexicons is, of course, not identical to the assumption of language selectivity (i.e., bilinguals may have two separate lexicons that can be activated simultaneously, e.g., Kroll, Van Hell, Tokowicz, & Green, 2010). The point here, however, is that for different-script bilinguals, orthographic representations must be stored in a language-selective way because the orthographic features of one language do not overlap with those of the second language. Although it seems reasonable to further assume that the two languages would share conceptual representations, whether the two languages share phonological representations or not would be an open question. This question is the focus of the present research. In the present study, we examined whether the phonological information used in reading is represented and, hence, activated, language selectively for different-script bilinguals. The expectation is that if phonological representations are stored in separate, language-selective lexicons, linked only to the orthographic representations for their specific language, one should not observe cross-script phonological priming effects. In contrast, if those phonological representations are stored in an integrated fashion, then phonological priming effects should be observed.

Consider, for example, the situation for Japanese-English bilinguals. Japanese words are written in Kana or Kanji scripts (e.g., "ネコ" and "猫" for "cat") and are not at all orthographically similar to their English translation equivalents because English words are written in an alphabetic (Roman) script.[1] However, the two languages do share phonemes, and the Japanese vocabulary does include a number of loan words from English that are phonologically similar to their English translation equivalents and to other English words. Although these translation equivalents rarely have exactly the same pronunciation because the syllabic system in English is based on a Consonant-Vowel-Consonant (CVC) structure, whereas the Japanese syllabic system is based on a mora (CV) structure (Kureta, Fushimi, & Tatsumi, 2006), we will refer to these word pairs as cognates because they are as similar in phonology as the structure of the two languages will allow. For example, the word "mask" is pronounced as /mask/ in English, and its Japanese translation ("マスク") is pronounced as /masuku/, with the extra vowels added to accommodate the Japanese moraic system. In the

[1] The Kana and Kanji scripts appear together regularly in normal text. Kanjis are orthographically deep morphological characters; each character has a meaning (e.g., 火 translates as "fire"). Kana scripts (Katakana and Hiragana), in contrast, use orthographically shallow syllabic characters, which makes Kana scripts somewhat similar to alphabetic scripts (e.g., カナ, where カ is pronounced "ka" and ナ is pronounced "na"). Cognates (which are often loan words from English) are normally written in Katakana, whereas noncognates are typically written in Kanji.

present experiment, these types of words (i.e., cognate translation primes) and another set of Japanese words that are phonologically similar but conceptually unrelated to English words (i.e., phonological primes) were the stimuli used.

There are now a few experiments in the literature that provide some evidence for integrated phonological representations for different-script bilinguals. For example, Gollan, Forster and Frost (1997, Experiment 1) compared the size of masked translation priming effects for cognates and noncognates with Hebrew-English bilinguals using a lexical decision task. When an L1 prime was followed by an L2 target, Gollan et al. found that the cross-script masked translation priming effect was larger for cognates (פילטר/feelter/-FILTER vs. גרגיר/gargir/-FILTER) than for noncognates (ארמון/armon/-CASTLE vs. סיגלית/sigalit/- CASTLE). Gollan et al. proposed that the larger priming effect observed for cognates was likely due to the overlapping phonology available for cognate translation primes. If this proposal is correct, this result would provide support for the language nonselective view of phonological representations.

The proposal that overlapping phonological features are the locus of the cognate advantage for different-script bilinguals has received empirical support from Voga and Grainger (2007). In their masked priming experiments, the pattern of priming effects for cognate and noncognate translation equivalents was examined with Greek-French bilinguals. In these experiments, translation priming effects for cognates were measured using two types of conceptually unrelated Greek primes: primes that were phonologically unrelated to the target and primes that were phonologically similar to the target. Voga and Grainger predicted that if the cognate advantage was indeed due to shared phonology, then this advantage would be eliminated when phonologically similar primes were used as controls. Their results were consistent with this prediction. When priming effects were measured against phonologically unrelated primes, cognates produced a significantly larger priming effect than noncognates, replicating the pattern reported by Gollan et al. (1997). When priming effects were measured against phonologically similar primes, however, cognates and noncognates produced comparable priming effects. Voga and Grainger's results supported the hypothesis that the advantage for cognates in their experiment was specifically due to the impact of phonology. The fact that lexical decision latencies were about 20 ms faster with phonologically similar primes than with phonologically unrelated primes (Voga & Grainger, 2007, Experiment 3) provided additional support for this conclusion, although this phonological priming effect was not tested for statistical significance.

There are also a few studies that directly examined the effect of phonology between L1 primes and L2 targets for different-script bilinguals. For Korean-English bilinguals, Kim and Davis (2003, Experiment 2) found a significant cross-language masked phonological priming effect with a 50 ms prime duration. That is, when a homophonic Korean word primed an English target (e.g., 풀 - PULL), naming latencies for the target were significantly faster than when a phonologically unrelated Korean word was the prime. A phonological priming effect for Korean-English bilinguals was also reported in a naming task in a study by Lee, Kim and Katz (2004), who used nonword homophonic primes and longer prime durations (140 and 250 ms prime durations). These data support the idea that there are integrated phonological representations for readers of English and Korean. However, given that both studies used a naming task, it is possible that those representations were output-level representations, representations that are not required in normal reading. Better evidence, therefore, would come from a demonstration that the same homophone primes facilitate responses in a lexical decision task, one that does not necessarily require the activation of phonological information. Kim and Davis did use a lexical decision task in one of their experiments (Experiment 1); unfortunately, the results were essentially equivocal with respect to this question, because although the Korean homophone primes facilitated responses to the English targets by 18 ms in that task, the effect was not statistically significant.

What may be the best evidence for a cross-script phonological priming effect comes from an experiment reported by Dimitropoulou, Duñabeitia and Carreiras (2011). Dimitropoulou et al. examined masked phonological priming effects for Greek-Spanish bilinguals using a lexical decision task. In Experiment 1, Spanish targets were primed by either phonologically similar Greek words or phonologically unrelated Greek words. To the extent possible (given that the scripts are different), Dimitropoulou et al. manipulated the orthographic similarity between the Greek and Spanish words in addition to their phonological similarity. For the orthographically similar pairs, there was no masked phonological priming effect; response latencies to Spanish targets (e.g., ocio, /ˈoθio/) primed by phonologically similar Greek words (e.g., όριο, /ˈorio/) were not statistically different from those primed by phonologically unrelated Greek words (e.g., βήμα, /ˈvima/). In fact, there was a trend toward inhibition (an 8 ms effect) for such orthographically and phonologically similar prime-target pairs.

Dimitropoulou et al. (2011) suggested that the lack of priming for these orthographically similar pairs was due to lateral inhibition operating between orthographic representations of the two languages even though they involved different scripts. Hence, any facilitation due to phonological overlap was cancelled out by that inhibition effect. This claim was supported by the observation of a significant phonological priming effect for the orthographically dissimilar pairs: response latencies to Spanish targets (e.g., fibra, /ˈfiβra/) were significantly faster when phonologically similar Greek words were used as primes (e.g., φύτρο, /ˈfitro/) than when phonologically unrelated Greek words were used as primes (e.g., τραγί, /traˈɣi/).

The significant masked phonological priming effect reported by Dimitropoulou et al. (2011) for orthographically dissimilar pairs suggest that for different-script bilinguals, the representation of phonology is integrated, such that phonological activation in one language influences phonological activation in the other language. What needs to be noted, however, is that Greek, like French and Spanish, is an alphabetic language, and there is a strong similarity between Greek and Spanish scripts (unlike the scripts for English and Hebrew, English and Korean, or English and Japanese). Thus, the orthographic representations of Greek-Spanish bilinguals (or Greek-French bilinguals) may be reasonably well integrated, a possibility underscored by the fact that Dimitropoulou et al.'s priming effect varied as a function of the "orthographic similarity" of the words in the two languages. Therefore, it is unclear whether Dimitropoulou et al.'s or Voga and Grainger's (2007) results and conclusions can be generalised to bilinguals whose languages involve scripts that are truly orthographically different. The present research addresses this question and considers the implications for models of bilingual lexical representation.

THE PRESENT RESEARCH

In the present experiment, the participants were Japanese-English bilinguals. The experiment was motivated by two questions that previous studies have identified. First, we sought to determine the extent to which phonological similarity facilitates lexical decision responses to targets in a cross-language masked priming paradigm using different-script languages. To do so, we designed our experiment so that we could measure a basic cross-script masked phonological priming effect and compare this effect with the pattern of the cross-script cognate translation priming effect. Second, we sought to determine the effect of processing fluency on phonological and cognate translation priming (assuming phonological priming effects would be obtained) by manipulating target frequency and by assessing the effect of L2 proficiency. As noted, Gollan et al. (1997) found that the cross-script masked translation priming effect was larger for cognates than for noncognates in their lexical decision experiments. In addition, Gollan et al. reported that this cognate advantage was found mainly for their less proficient bilinguals: in their posthoc analysis, the translation priming effect increased selectively for cognates only for the group of participants with higher error rates to the L2 targets (for the purposes of their analysis, Gollan et al. assumed that higher error rates reflected lower L2 proficiency). Gollan et al. concluded that the larger cognate advantage for the less proficient bilinguals was due to their greater reliance on phonological codes when making lexical decisions. One should also note, however, that Gollan et al.'s results were somewhat different from those of Duyck et al. (2004), who found that the phonological priming effect in a perceptual identification task was not modulated by L2 proficiency (i.e., when comparing simultaneous vs. late bilinguals). Thus, at present, it is not clear whether processing fluency of L2 targets influences the level of phonological (or cognate) priming in a cross-script masked priming task, and hence, this may be an important consideration when looking for evidence of cross-script phonological priming in Japanese-English bilinguals. Our study is the first to examine the effect of L2 proficiency and target frequency on the masked cognate and phonological priming effects for different-script bilinguals.

In the present experiment, we assessed the effect of processing fluency of L2 targets on phonological priming in two ways. First, we manipulated the printed frequency of the targets; half were high-frequency words, and half were low-frequency words. High-frequency targets should be more familiar and more easily processed than low-frequency targets because bilinguals read high-frequency words more often than low-frequency words. Second, we examined individual differences in priming as a function of performance on a test of English language skills, the Test of English as International Communication (TOEIC).[2] According to Gollan et al.'s (1997) analysis, less proficient bilinguals (i.e., those with lower scores on the TOEIC) will rely on phonological information to a greater extent when making lexical decisions, which should in turn lead to a larger phonological priming effect. If, as Gollan et al.'s results suggest, the magnitude of the phonological facilitation depends on the degree of reliance on phonological information (and if reliance on phonological information is, in turn, related to the processing fluency of L2 words), then any phonologically-based priming effect should be larger for low-frequency targets than for high-frequency targets, and also larger for less proficient bilinguals than for more proficient bilinguals.

[2] The TOEIC is administered by the Educational Testing Service (ETS) and consists of two sections of 100 questions each (listening comprehension and reading comprehension). The test requires about 2.5 hours to complete and assesses a broad range of English skills, especially in business settings. Test scores range from 0 to 990, with higher scores indicating greater fluency in English. In Japan, approximately 750,000 people take the test annually, and the test scores are accepted by many schools and organisations as a measure of English proficiency. Bilinguals with scores in the 860–990 range are considered the most proficient (the "gold" certification), and those with scores in the 730–855 range are considered to be less proficient but still highly fluent (the "blue" certification).

To summarise, our experiment addressed two key issues. First, if the phonological representations for a bilingual's two languages are integrated even though those languages use different scripts, then lexical decision performance should be facilitated when L2 targets (English words) are primed by phonologically similar L1 words (Japanese words), relative to when the same L2 targets are primed by phonologically unrelated L1 words (a phonological priming effect). In contrast, if the phonological representations for the two languages are separate, then there should be no phonological priming effect. Second, assuming that there is cross-language phonological activation and priming, if the processing fluency of L2 targets is important, then larger priming effects are expected for low-frequency targets than for high-frequency targets, and also for less proficient bilinguals than for more proficient bilinguals.

METHOD

Participants

Seventy-six undergraduate and graduate students from Waseda University (Tokyo, Japan) participated in this experiment for 1000 Yen (about US $12.00). All participants had completed the TOEIC and had scores higher than 700 ($M = 839$, range = 700–990). The participants reported that they had studied English for an average of 10.6 years ($SD = 3.0$).

Stimuli

One hundred and twenty English words were selected as targets. Half of the targets were low-frequency words ($M = 14.9$ occurrences per million, $SD = 9.6$; Kućera & Francis, 1967) and half were high-frequency words ($M = 204.3$ occurrences per million, $SD = 149.7$). The high- and low-frequency words were very similar with respect to mean word length (4.6 vs. 4.7, respectively) and mean number of orthographic neighbours (6.4 and 6.4, respectively). Each target (e.g., GUIDE) was paired with three types of Japanese Katakana word primes (see Table 1): (1) a cognate translation equivalent prime (e.g., ガイド, /gaido/, *guide*), (2) a phonologically similar but conceptually unrelated prime (e.g., サイド, /saido/, *side*), and (3) a phonologically and conceptually unrelated prime (e.g., コール, /koRru/, *call*). Phonologically similar primes differed from cognate translation primes by one character (i.e., one syllable). As a result, phonologically similar primes and translation primes differed from each other by one to three phonemes, with the majority differing by two phonemes. (The phonological primes and cognate translation primes had 70% overlapping phonemes on average, 70.3% and 69.6% for the primes preceding low- and high-frequency targets, respectively.)[3] The initial purposes of using cognate translation primes were (1) to compare the magnitude of any phonological priming effect with that of the cognate translation priming effect, which would allow us to determine the additional impact of the conceptual overlap between the prime and the target, and (2) to allow us to demonstrate that our masked priming procedure was effective in the event that

[3] Quantifying the phonological overlap between Japanese primes and English targets is not straightforward because the phonemes used in English and Japanese are not identical. Due to the constraints on stimulus selection, the phonologically similar primes were phonologically slightly less similar to their targets than the cognate translation primes were to their targets. We were, however, able to quantify and equate phonological similarity between translation primes and phonological primes in the two frequency categories by computing the number of overlapping phonemes in the pairs of Japanese prime words.

phonological priming was not observed. As will be discussed, an additional benefit was that these primes provided useful information concerning the nature of the interactions between the cognate priming manipulation and the factors of word frequency and bilingual proficiency.

The normative frequency of the primes was not manipulated but was instead controlled such that all of the primes were low-frequency words. The mean normative frequencies of the cognate translation primes, phonological primes, and unrelated primes for low-frequency targets were 10.9 ($SD = 10.1$), 8.2 ($SD = 9.5$), and 7.0 ($SD = 7.1$); for high-frequency targets, the mean normative frequencies of the three types of primes were 10.4 ($SD = 21.5$), 4.7 ($SD = 28.6$), and 7.0 ($SD = 6.8$), respectively (Amano & Kondo, 2000).[4] These primes had the same mean character length ($M = 3.4$). Three counterbalanced lists with matching lexical characteristics were created so that the same targets could be presented to all participants but each participant saw only one of the prime-target pairings. The Japanese-English prime-target pairs are listed in the Appendix.

One hundred and twenty English nonwords were selected from the English Lexicon Project database (Balota et al., 2007) for the lexical decision task. These were matched to the word targets with respect to length and number of neighbours ($M = 4.8$ and 6.2, respectively). One hundred and twenty Japanese words were selected as primes for these nonword targets. The mean normative frequency of the Japanese primes was 7.8 ($SD = 11.4$), and their mean length was 3.5 characters. Because there are no translation equivalents for nonwords, prime type was not manipulated for nonwords. Thus, for the nonword targets, only one presentation list was necessary and all participants saw the same pairings. In Gollan et al.'s (1997) and Voga and Grainger's (2007) studies, both cognates and noncognates were presented. To evaluate whether this factor might be important, half of the participants ($n = 36$) were also presented with 120 Japanese-English word pairs in which their translation equivalents were noncognates.[5] For those participants, 120 English nonwords primed by Japanese words (all of which had translations equivalents that were noncognates) were also presented to maintain a word/nonword ratio of 50/50. Thus, for the participants presented with noncognate fillers, the experiment consisted of 480 trials in total, whereas for the participants not presented with fillers, the experiment consisted of 240 trials in total.

Apparatus and procedure

Each participant was tested individually. The experiment was programmed using the DMDX software package (Forster & Forster, 2003). Stimuli were presented on a 21-inch video display driven by a desktop microcomputer. Each trial began with the presentation of a forward mask (######) for 500 ms followed by a 50 ms presentation of a Japanese prime. Immediately following the prime, an English target

[4] Normative frequencies were based on the NTT database (Amano & Kondo, 2000), which provides frequency counts based on a corpus of 287,792,797 words. The normative frequencies reported here are per million words and are derived by dividing the original frequency values by 287.8.

[5] For the filler noncognate Japanese-English word pairs, half of the targets were primed by Japanese translation equivalents, and the other half were primed by unrelated Japanese words. Only a single presentation list was necessary. The lexical characteristics of the noncognate primes and targets were matched to those in the cognate condition, except that the Japanese noncognate primes were shorter in length ($M = 2.0$ for the noncognates vs. 3.4 for the cognates) and the majority of those words were presented in Kanji.

TABLE 1
Examples of translation, phonological, and unrelated Japanese cognate primes (phonemic transcription, English translation) and low- and high-frequency English targets used in the study

Prime type			*Target*
Translation	*Phonological*	*Unrelated*	*Low-frequency*
ガイド (/gaido/, *guide*)	サイド (/saido/, *side*)	コール (/koRru/, *call*)	GUIDE
			High-frequency
ステージ (/suteRzi/, *stage*)	コテージ (/koteRzi/, *cottage*)	オーバー (/oRbaR/, *over*)	STAGE

was presented (in upper-case letters); the target remained on the display until the participant made a response. The task was to make a lexical decision to the target. Participants were instructed to make their decisions as quickly and accurately as possible by pressing the *yes* or *no* button on a response box placed in front of them. Each target was flanked by brackets (>>>> and <<<<) so that the primes were completely masked by the targets (this was necessary because some of the Japanese primes were slightly longer than their English targets). Participants completed 16 practice trials to familiarise themselves with the task prior to the collection of data.

RESULTS

The data from four participants were excluded from all analyses due to high error rates (> 20%); the analyses were therefore based on data from 72 participants. Response latencies < 300 ms or > 1,700 ms were considered outliers; response latencies that fell outside of these limits were replaced by these values (this treatment applied to < 0.5% of all "word" responses). The data for four low-frequency targets (*radar*, *cue*, *veil,* and *lens*) were excluded from all analyses because the average error rate for each of these items was > 50%.

Preliminary analyses showed that the list context (whether the critical targets were presented with noncognate fillers or without noncognate fillers) did not significantly interact with any priming effect either for response latencies or for errors (all *p*s > .10). Therefore, the data were collapsed across the list context conditions. The mean lexical decision latencies for correct responses and the mean error rates were analysed using a

TABLE 2
Mean lexical decision latencies (in ms) and percentage errors for English word targets primed by translation, phonological, and unrelated Japanese primes

	Prime type			*Priming effect*	
	Translation (T)	*Phonological (P)*	*Unrelated (UR)*	*Translation (UR – T)*	*Phonological (UR – P)*
LF targets	633 (6.4)	710 (14.3)	738 (18.3)	105 (11.9)	28 (4.0)
HF targets	591 (3.5)	643 (7.6)	674 (9.2)	83 (5.7)	31 (1.6)

Note: The mean lexical decision latency and percentage errors for nonword targets were 743 ms and 9.8%, respectively. LF targets, low-frequency targets; HF targets, high-frequency targets.

2 (target frequency: low, high) × 3 (prime type: translation, phonological, unrelated) repeated measures analysis of variance (ANOVA). Both subject (F_s) and item (F_i) analyses were carried out. In the subject analyses, target frequency and prime type were within-subject factors. In the item analyses, target frequency was a between-item factor and prime type was a within-item factor. Table 2 lists the mean response latencies and error rates from the subject analyses.

There was a significant main effect of target frequency for response latencies, $F_s(1, 71) = 139.79$, $p < .001$, $MSE = 2{,}527.1$; $F_i(1, 114) = 30.48$, $p < .001$, $MSE = 10{,}515.6$, and for errors, $F_s(1, 71) = 68.93$, $p < .001$, $MSE = 61.3$; $F_i(1, 114) = 21.01$, $p < .001$, $MSE = 162.1$. Lexical decisions to low-frequency targets were slower and more error prone (694 ms, 13.0%) than lexical decisions to high-frequency targets (636 ms, 6.8%). The main effect of prime type was also significant for response latencies, $F_s(2, 142) = 101.60$, $p < .001$, $MSE = 3{,}309.2$; $F_i(2, 228) = 138.60$, $p < .001$, $MSE = 2{,}246.1$, and for errors, $F_s(2, 142) = 47.43$, $p < .001$, $MSE = 61.6$; $F_i(2, 228) = 49.01$, $p < .001$, $MSE = 47.6$. There was a large translation priming effect, with responses to targets primed by cognates being the fastest and most accurate (612 ms, 5.0%) and those to targets primed by unrelated words being the slowest and least accurate (706 ms, 13.8%). Responses to targets primed by phonologically similar words were intermediate in latency and errors (677 ms, 11.0%). Most important was the significant interaction between target frequency and prime type for response latencies, $F_s(2, 142) = 5.10$, $p < .01$, $MSE = 1{,}311.2$; $F_i(2, 228) = 3.12$, $p < .05$, $MSE = 2{,}246.1$, and for errors, $F_s(2, 142) = 8.18$, $p < .001$, $MSE = 41.9$; $F_i(2, 228) = 5.69$, $p < .01$, $MSE = 47.6$.

To evaluate the significant interaction between target frequency and prime type, separate planned interaction contrasts were carried out to assess the phonological and cognate translation priming effects. First, to assess the phonological priming effect, responses to targets primed by phonologically similar words and unrelated words were compared using a 2 (prime type: phonological, unrelated) × 2 (target frequency: low, high) repeated measures ANOVA. The main effect of prime type was significant for response latencies, $F_s(1, 71) = 23.02$, $p < .001$, $MSE = 2{,}747.4$; $F_i(1, 114) = 25.46$, $p < .001$, $MSE = 2{,}595.9$, and for errors, $F_s(1, 71) = 8.63$, $p < .01$, $MSE = 67.6$; $F_i(1, 114) = 7.35$ $p < .01$, $MSE = 63.7$. Averaged across target frequency, phonologically similar primes facilitated responses by 30 ms in terms of response latencies and by 2.8% in terms of errors. The interaction between target frequency and prime type was not significant either for response latencies (both Fs < 1) or for errors, $F_s(1, 71) = 2.15$, $p > .10$; $F_i(1, 114) = 1.26$, $p > .10$. As can be seen in Table 2, the phonological priming effect for low-frequency targets (28 ms, 4.0%) was very similar to the phonological priming effect for high-frequency targets (31 ms, 1.6%). These results suggest that L2 processing fluency (as indexed by word frequency) had no effect on phonological priming.

Second, to assess the cognate translation priming effect, responses to targets primed by cognates and unrelated words were compared using a 2 (prime type: cognate translation, unrelated) × 2 (target frequency: low, high) repeated measures ANOVA. The main effect of prime type was significant for response latencies, $F_s(1, 71) = 168.83$, $p < .001$, $MSE = 3{,}806.6$; $F_i(1, 114) = 296.68$, $p < .001$, $MSE = 2{,}022.5$, and for errors, $F_s(1, 71) = 81.12$, $p < .001$, $MSE = 69.1$; $F_i(1, 114) = 105.19$, $p < .001$, $MSE = 42.6$. Averaged across target frequency, the cognate translation priming effect was 94 ms in terms of response latencies and 8.8% in terms of errors. In addition, there was a significant interaction between prime type and target frequency for response latencies, $F_s(1, 71) = 7.21$, $p < .01$, $MSE = 1{,}231.4$; $F_i(1, 114) = 5.17$, $p < .05$,

TABLE 3
Mean lexical decision latencies (in ms) and percentage errors for English word targets primed by translation, phonological, and unrelated Japanese primes for the bilinguals with the highest and the lowest TOEIC scores

	Prime type			*Priming effect*	
	Translation (T)	*Phonological (P)*	*Unrelated (UR)*	*Translation (UR – T)*	*Phonological (UR – P)*
Bilinguals with the highest TOEIC scores					
LF targets	608 (4.4)	667 (10.3)	701 (12.1)	93 (7.7)	34 (1.8)
HF targets	577 (3.1)	622 (7.5)	633 (6.7)	56 (3.6)	11 (–0.8)
Bilinguals with the lowest TOEIC scores					
LF targets	651 (8.9)	741 (15.8)	774 (23.3)	123 (14.4)	33 (7.5)
HF targets	595 (3.5)	661 (7.7)	704 (10.4)	109 (6.9)	43 (2.7)

$MSE = 2{,}022.5$, and for errors, $F_s(1, 71) = 19.37$, $p < .001$, $MSE = 34.8$; $F_i(1, 114) = 12.51$, $p < .01$, $MSE = 42.6$. Unlike the phonological priming effect, the cognate translation priming effect was larger for low-frequency targets (105 ms, 11.9%) than for high-frequency targets (83 ms, 5.7%), which suggests that for cognate translation primes there was an effect of L2 processing fluency (as indexed by word frequency) on the priming effect.[6,7]

L2 proficiency analysis based on participants' TOEIC scores

To determine if the magnitude of the priming effect varied as a function of an individual's level of L2 processing fluency, as measured by an individual's TOEIC score, the phonological and cognate translation priming effects for the 24 bilinguals with the lowest TOEIC scores ($M = 760$) and the 24 bilinguals with the highest TOEIC scores ($M = 927$), $t(46) = 14.01$, $p < .001$) were compared (a tertile split), while maintaining the counterbalancing of the stimulus presentation lists and the list context. The mean response latencies and error rates from the subject analyses are listed in Table 3.

As expected, the bilinguals with higher TOEIC scores responded to targets significantly faster (635 ms) and made fewer errors (7.4%) than the bilinguals with

[6] We should point out that some of the difference between the cognate translation priming effect and the phonological priming effect could have been due to the fact that the degree of phonological similarity was slightly larger for the cognate translation pairs than for the phonologically similar pairs. It seems very unlikely, however, that this small difference could account for the substantial difference between the size of the cognate translation priming effect (94 ms) and that of the phonological priming effect (30 ms).

[7] Recall that each target (e.g., GUIDE) was primed by a cognate translation prime (e.g., ガイド, /gaido/, *guide*) and a phonologically similar prime (e.g., サイド, /saido/, *side*). About half of the phonologically similar primes shared the initial phoneme with their paired cognate translation prime, whereas the remainder did not. This generally meant that whereas all of the cognate translation primes shared initial phonemes with their targets, the same was true only for about half of the phonologically similar primes. To evaluate the extent to which this difference may have affected the contrast between cognate translation priming and phonological priming, we compared the priming effect for phonologically similar primes that shared their initial phoneme with their paired cognate translation prime to the priming effect for phonologically similar primes that did not share their initial phoneme with their paired cognate translation prime. In this posthoc analysis, although the former primes produced slightly more priming (32 ms) than the latter (23 ms), this difference was far from significant, $F_s < 1$; $F_i(1, 114) = 1.41$, $p > .10$. Therefore, it does not appear that very much of the difference between the phonologically similar and cognate translation prime conditions could have been due to a difference on this dimension.

lower TOEIC scores (688 ms and 11.6%), $F_s(1, 46) = 3.15$, $p = .08$, $MSE = 64{,}266.3$; $F_i(1, 114) = 119.04$, $p < .001$, $MSE = 5{,}122.4$, for response latencies, and $F_s(1, 46) = 10.47$, $p < .01$, $MSE = 124.2$; $F_i(1, 114) = 24.72$, $p < .001$, $MSE = 127.8$, for errors. L2 proficiency significantly interacted with target frequency, such that the frequency effect was larger for the bilinguals with lower TOEIC scores (69 ms and 8.8% effects) than for the bilinguals with higher TOEIC scores (48 ms and 3.1% effects), for latencies, $F_s(1, 46) = 3.23$, $p = .08$, $MSE = 2{,}328.4$; $F_i(1, 114) = 4.82$, $p < .05$, $MSE = 5{,}122.4$, and for errors, $F_s(1, 46) = 12.87$, $p < .01$, $MSE = 43.6$; $F_i(1, 114) = 10.70$, $p < .01$, $MSE = 127.8$.

In terms of the pattern of priming effects, there was a significant interaction between prime type and L2 proficiency for response latencies, $F_s(2, 92) = 3.81$, $p < .05$, $MSE = 2{,}784.4$; $F_i(2, 228) = 4.43$, $p < .05$, $MSE = 7{,}870.7$, and for errors, $F_s(2, 92) = 3.10$, $p = .05$, $MSE = 59.4$; $F_i(2, 228) = 4.29$, $p < .05$, $MSE = 103.8$. The three-way interaction between prime type, target frequency, and L2 proficiency was not significant for response latencies or for errors, $F_s(2, 92) = 1.39$, $p > .10$, $MSE = 1{,}267.0$; $F_i < 1$, and $F_s < 1$; $F_i < 1$, respectively.

Planned interaction contrasts assessing the phonological and cognate translation priming effects showed that the pattern of effects mirrored the effects observed in the analysis of low- and high-frequency targets. For the phonological priming effect, in terms of response latencies, the two groups did not differ significantly in the magnitude of the priming effect: averaged across target frequency, the priming effect was 23 ms for the bilinguals with higher TOEIC scores and 38 ms for the bilinguals with lower TOEIC scores, $F_s(1, 46) = 1.08$, $p > .10$, $MSE = 2{,}697.7$; $F_i(1, 114) = 1.38$, $p > .10$, $MSE = 8{,}584.7$, although for errors, the priming effect was larger for the bilinguals with lower TOEIC scores (a 5.1% effect vs. a 0.5% effect for the bilinguals with higher TOEIC scores), $F_s(1, 46) = 4.32$, $p < .05$, $MSE = 57.9$; $F_i(1, 114) = 3.74$, $p = .06$, $MSE = 161.1$. In contrast, for the cognate translation priming effect, the priming effect was significantly larger for the bilinguals with lower TOEIC scores, in terms of response latencies (116 vs. 75 ms for the bilinguals with higher TOEIC scores), $F_s(1, 46) = 6.98$, $p < .05$, $MSE = 2{,}980.7$; $F_i(1, 114) = 7.29$, $p < .01$, $MSE = 9{,}462.6$, and in terms of errors (a 10.7% effect vs. a 5.7% effect for the bilinguals with higher TOEIC scores), $F_s(1, 46) = 4.04$, $p = .05$, $MSE = 74.3$; $F_i(1, 114) = 9.42$, $p < .01$, $MSE = 77.3$. Thus, the two complimentary ways of testing for an effect of L2 processing fluency on phonological and cognate translation priming (L2 target frequency and L2 proficiency as measured by TOEIC scores) produced comparable results.[8]

DISCUSSION

The purpose of this experiment was to determine if a cross-script phonological priming effect would be observed for different-script bilinguals using a lexical decision

[8] The same conclusion was supported based on regression analyses in which the relationship between TOEIC scores and priming effects was examined using mixed-model regression analyses, one for the translation priming effect and one for the phonological priming effect (for both analyses N = 72). Because the subject means for these priming effects were based on three counterbalancing lists, the list factor was effect-coded and included in the analyses. These analyses showed that TOEIC scores accounted for a significant proportion of the variance in the cognate translation priming effect, $t(68) = 2.16$, $p < .05$, $\beta = -.22$, with lower TOEIC scores associated with larger priming effects. In contrast, TOEIC scores did not account for a significant proportion of the variance in the phonological priming effect, $t(68) < 1$.

task with masked primes, and if so, whether such an effect would be modulated by L2 target processing fluency. In previous masked priming studies with same-script bilinguals, phonological priming effects have been reported (e.g., Brysbaert et al., 1999; Duyck et al., 2004), leading to the conclusions that phonological representations in the two languages are integrated when those languages share a script and that those representations are automatically activated by words in either language. The question here was whether this is also true for the processing of different-script languages, given the small number of studies that have examined phonological priming effects for different-script bilinguals (Dimitropoulou et al., 2011; Gollan et al., 1997; Kim & Davis, 2003; Voga & Grainger, 2007) and the possibility that phonological representations may be more language-selective when a bilingual's languages do not share a script.

We found that lexical decisions to L2 targets were facilitated not only by cognate translation primes (a 94 ms effect) but also by phonologically similar primes (a 30 ms effect) presented in L1. The significant phonological facilitation observed nicely converges with the results of Dimitropoulou et al. (2011), who reported that for Greek-Spanish bilinguals, phonologically similar but orthographically dissimilar primes facilitated lexical decisions to targets, even though phonologically and orthographically similar primes did not. Dimitropoulou et al. explained the latter result as being due to inhibitory processes playing an important role when the primes and targets have some orthographic similarity. This pattern also led Dimitropoulou et al. to suggest that phonological priming effects may be more readily observed with languages that do not share orthographies, because orthographic competition between primes and targets with similar orthographies may make it difficult to observe a facilitatory phonological priming effect. Our results, obtained using languages with completely different scripts (English and Japanese), support this suggestion. The more important point is that both sets of results clearly support the view that a bilingual's phonological representations are integrated even when the two scripts are quite different.[9]

The most straightforward interpretation of the phonological priming observed in the present study is that phonological representations are shared across languages, even when orthographic representations are not. This conclusion is easily accommodated by models of bilingual lexicons that assume distributed, yet highly interactively connected sublexical and lexical phonological (and semantic) features, such as the BIA+ model (Dijkstra & Van Heuven, 2002). In such a localist-connectionist framework, it is possible to accommodate shared phonological representations without assuming the same structure for orthographic representations. Of course, theoretically, one could argue that different-script bilinguals actually possess two separate sets of phonological representations with strong linkages between them. Distinguishing this type of "integrated" representations from one in which the words in the two languages activate a single set of shared representations would not be possible on the basis of the present data. In fact, it is not clear what data would allow

[9] While revising this paper for resubmission, we were alerted to a newly published article by Zhou, Chen, Yang, and Dunlap (2010) examining masked cross-language homophone priming for Chinese-English bilinguals. Their lexical decision results were consistent with ours; they reported significant homophone priming effects, and the size of the effect did not differ significantly as a function of English proficiency. Zhou et al. did not examine effects of target frequency nor the impact of L2 proficiency on cognate translation priming effects, however.

one to distinguish between these two alternatives. In either case, however, the results of the present study clearly show that phonological representations are activated in a language nonselective fashion even for different-script bilinguals, individuals whose orthographic representations are presumably activated language selectively.

We also examined the question of whether the degree of phonological facilitation was greater when L2 processing fluency was low, as suggested by Gollan et al. (1997). Recall that in Gollan et al.'s study, the translation priming effect (for cognates) was larger for participants with higher error rates. Gollan et al. argued that the cognate advantage increased for these participants because reliance on phonological information during lexical decision-making tends to increase if bilinguals are less proficient in L2. In contrast, Duyck et al. (2004) reported that the phonological priming effect was identical for more and less proficient Dutch-French bilingual groups, a result that does not suggest that reliance on phonological information is modulated by L2 proficiency. In addition, Dimitropoulou et al. (2011) reported comparable phonological priming effects when an L1 prime was followed by an L2 target (in their Experiment 1) and when an L2 prime was followed by a—presumably more proficiently processed—L1 target (in their Experiment 2). To evaluate the impact of L2 processing fluency on the phonological priming effect, we compared priming effects for high- and low-frequency targets and for bilinguals with high and low scores on the TOEIC.

The large word frequency effect in our data (a 58 ms effect on average) clearly demonstrated that the L2 low-frequency targets were more difficult to process than the L2 high-frequency targets. With respect to the cognate translation priming effect, our results are consistent with Gollan et al.'s (1997) results, in that we also found that the effect is modulated by the processing difficulty of the targets; in our experiment, the cognate translation priming effect was significantly larger for low-frequency targets (a 105 ms effect) than for high-frequency targets (a 83 ms effect). On the other hand, consistent with Duyck et al.'s (2004) results and in contrast to Gollan et al.'s claims about phonological processing, the magnitude of the phonological priming effect was statistically equivalent for high- and low-frequency targets (31 and 28 ms effects, respectively). A similar pattern of results was also observed when participants were grouped into more and less proficient bilinguals depending on their TOEIC scores: whereas the phonological priming effect was similar for the two groups (23 and 38 ms effects, respectively), the cognate translation priming effect was significantly smaller for the more proficient bilinguals than for the less proficient bilinguals (75 and 116 ms effects, respectively). Our data, therefore, lead to the conclusion that overall, L2 processing fluency modulates the cognate translation priming effect but has little impact on the phonological priming effect.

Of course, we cannot rule out the possibility that L2 proficiency does have at least a minor impact on the phonological priming effect. In fact, as noted, the phonological priming effect on errors was significantly larger for the less proficient bilinguals than for the more proficient bilinguals (a 5.1% effect vs. a 0.5% effect; see Table 3). In addition, although the phonological priming effects for low-frequency targets were comparable for more and less proficient bilinguals (34 vs. 33 ms), for high-frequency targets, the priming effect was larger for less proficient bilinguals (43 ms) than for more proficient bilinguals (11 ms). (The three-way interaction between prime type, target frequency, and L2 proficiency was not significant, however.) Taken together, these differences suggest that it is possible that the phonological priming effect is not completely independent of L2 proficiency and that if we had tested bilinguals who were much less proficient in L2 than our lower proficiency bilinguals we might have observed a significant difference between more and less proficient bilinguals in the size of the priming effect. At the very least, our results show that the cognate and phonological priming effects differ considerably in their sensitivity to L2 proficiency.

The role of phonology in bilingual word recognition

The different effects of processing fluency for cognate translation priming and phonological priming suggest that the simple phonological overlap between two languages and the conceptual overlap for translation equivalents have somewhat different impacts on bilingual word recognition. In particular, based on our results, when a masked prime is presented, its phonological representation appears to be activated automatically regardless of the differences between the two languages' scripts, leading to a facilitation of target processing if the prime and target (partially) share phonology. Because the phonological facilitation appears to be minimally affected by target frequency (and bilingual proficiency), the implication is that its effect is pre-lexical in nature.

In contrast, when an L1 prime and an L2 target are cognate translation equivalents, they share conceptual representations in addition to having phonological overlap. Thus, when an L2 target is a cognate translation of an L1 prime, the processes of both conceptual activation and phonological activation should be facilitated. As would be expected, and as was observed in the present experiment, the cognate translation priming effect would then be substantially larger than the phonological priming effect. The present results therefore support the idea that the locus of the translation priming effect is primarily via shared conceptual activation (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Kroll & Curley, 1988; Potter et al., 1984).

The present results also indicate that the process of retrieving conceptual representations, in contrast to the process of activating phonology per se, appears to be dependent on the strength of these correspondences given that the cognate translation priming effect was modulated by target frequency and bilingual proficiency. One theoretical framework that can account for this outcome is the lexical integrity hypothesis (Yap, Tse, & Balota, 2009). According to this account, high-frequency targets are retrieved in a more fluent manner than low-frequency targets because their representations are more stable and coherent and because they are closer to a recognition threshold (i.e., they are high in "lexical integrity"). Given this assumption, the lexical integrity hypothesis can provide an explanation for why high-frequency targets benefit to a lesser degree from the semantic context provided by cognate translation primes, and why more proficient bilinguals (i.e., individuals having richer and more stable L2 word representations) would show smaller cognate translation priming effects.

The lexical integrity hypothesis provides a nice framework for understanding why the cognate translation priming effect was modulated by target frequency and bilingual proficiency in our study. A key question would then be whether the absence of similar interactions for the phonological priming effect would be inconsistent with this framework. That is, although the phonological priming effect is due to the activation of sublexical representations, one might expect that those representations would vary in their integrity to some degree, particularly when integrity is measured in terms of bilingual proficiency. We can offer two possible explanations for the absence of an interaction between phonological priming and bilingual proficiency. First, lexical integrity may simply have less impact on sublexical phonological activation; that is, even if this process is modulated by the integrity of the phonological representation itself, it may be less affected by the nature (i.e., the coherence) of relationships between orthographic, phonological, and semantic representations. A second possibility is that even for lower proficiency bilinguals, sublexical representations (which are activated continually whenever a person is reading) are much more strongly developed than the lexical representations of even high-frequency words. Through repeated activation, they may have reached a high enough level of integrity that, in tasks like lexical decision, it is difficult to observe a sizeable effect of lexical integrity.

CONCLUSIONS

Our results indicate that phonological representations in bilinguals are integrated, even when those languages involve completely different scripts, and that the activation of these phonological representations when a word is read in one language is sufficient to facilitate target processing in the other language. Our results also show that the phonological priming effect is minimally, if at all, affected by target frequency and L2 proficiency, whereas the cognate translation priming effect is clearly modulated by these two factors. We conclude that phonological activation plays much the same role in visual word recognition for different-script bilinguals as it does for same-script bilinguals and monolinguals.

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APPENDIX 1

Japanese translation prime (with phonemic transcription), phonological prime (with phonemic transcription and English translation), unrelated prime (with phonemic transcription and English translation), English target. Phonemic transcriptions according to Tamaoka

Translation Prime		*Phonological Prime*			*Unrelated Prime*			*Low-frequency Target*
メダル	/medaru/	ペダル	/pedaru/	pedal	モード	/moRdo/	mode	medal
クッキー	/kuQkiR/	ラッキー	/raQkiR/	lucky	メソッド	/mesoQdo/	method	cookie
ピーク	/piRku/	パーク	/paRku/	park	ヨット	/joQto/	yacht	peak
ラケット	/rakeQto/	チケット	/cjikeQto/	ticket	アレンジ	/areNzi/	arrange	racket
ロケット	/rokeQto/	ポケット	/pokeQto/	pocket	チャイム	/tjaimu/	chime	rocket
ブーム	/buRmu/	ビーム	/biRmu/	beam	エラー	/eraR/	error	boom
チーズ	/cjiRzu/	ビーズ	/biRzu/	beads	カメラ	/kamera/	camera	cheese
リース	/riRsu/	ホース	/hoRsu/	hose/horse	ナイン	/naiN/	nine	lease
ギター	/gitaR/	スター	/sutaR/	star	シード	/siRdo/	seed	guitar
ラッシュ	/raQsju/	ダッシュ	/daQsju/	dash	ガソリン	/gasoriN/	gasoline	rush
メロディー	/merodiR/	パロディー	/parodiR/	parody	ハリケーン	/harikeRN/	hurricane	melody
テープ	/teRpu/	ロープ	/roRpu/	rope	ランチ	/raNcji/	lunch	tape
ヌード	/nuRdo/	ムード	/muRdo/	mood	ホラー	/horaR/	horror	nude
マスク	/masuku/	モスク	/mosuku/	mosque	ミール	/miRru/	meal	mask
タンク	/taNku/	リンク	/riNku/	link	トレー	/toreR/	tray	tank
ビール	/biRru/	シール	/siRru/	seal	テニス	/tenisu/	tennis	beer
スープ	/suRpu/	キープ	/kiRpu/	keep	ベンチ	/beNcji/	bench	soup
バス	/basu/	ロス	/rosu/	loss	ベル	/beru/	bell	bus
ケーブル	/keRburu/	ノーブル	/noRburu/	noble	ドクター	/dokutaR/	doctor	cable
ワックス	/waQkusu/	サックス	/saQkusu/	sax	ユーモア	/juRmoa/	humor	wax
ブーツ	/buRtu/	シーツ	/siRtu/	sheets	コピー	/kopiR/	copy	boots
ガイド	/gaido/	サイド	/saido/	side	コール	/koRru/	call	guide
ピーチ	/piRcji/	コーチ	/koRcji/	coach	ナイフ	/naihu/	knife	peach
ポスター	/posutaR/	マスター	/masutaR/	master	タレント	/tareNto/	talent	poster
レーダー	/reRdaR/	リーダー	/riRdaR/	leader	コマンド	/komaNdo/	command	radar
ベルト	/beruto/	ボルト	/boruto/	bolt	マーク	/maRku/	mark	belt
マップ	/maQpu/	カップ	/kaQpu/	cup	ボタン	/botaN/	button	map
イーグル	/iRguru/	ゴーグル	/goRguru/	goggle	リゾート	/rizoRto/	resort	eagle
キュー	/kjuR/	ニュー	/njuR/	new	パック	/paQku/	pack	cue
ゼロ	/zero/	キロ	/kiro/	kilo	ミニ	/mini/	mini	zero
スプーン	/supuRN/	ストーン	/sutoRN/	stone	セミナー	/seminaR/	seminar	spoon

Appendix 1 (*Continued*)

Translation Prime		*Phonological Prime*			*Unrelated Prime*			*Low-frequency Target*
バブル	/baburu/	バレル	/bareru/	barrel	カット	/kaQto/	cut	bubble
スタンプ	/sutaNpu/	スランプ	/suraNpu/	slump	シューズ	/sjuRzu/	shoes	stamp
ボウル	/bouru/	ボトル	/botoru/	bottle	タブー	/tabuR/	taboo	bowl
パネル	/paneru/	パール	/paRru/	pearl	ロック	/roQku/	rock/lock	panel
パイプ	/paipu/	パルプ	/parupu/	pulp	シネマ	/sinema/	cinema	pipe
リリース	/ririRsu/	リバース	/ribaRsu/	reverse	ジャンプ	/zjaNpu/	jump	release
ジム	/zimu/	ジン	/ziN/	gin	ビザ	/biza/	visa	gym
ラット	/raQto/	ラップ	/raQpu/	rap	コラム	/koramu/	column	rat
サラダ	/sarada/	サラミ	/sarami/	salami	シャツ	/sjatu/	shirt	salad
ライター	/raitaR/	ライダー	/raidaR/	rider	バラード	/baraRdo/	ballad	lighter
シャワー	/sjawaR/	シャドー	/sjadoR/	shadow	フライト	/huraito/	flight	shower
スカート	/sukaRto/	スカウト	/sukauto/	scout	タイトル	/taitoru/	title	skirt
センサー	/seNsaR/	センサス	/seNsasu/	census	デジタル	/dezitaru/	digital	sensor
メーカー	/meRkaR/	メーター	/meRtaR/	meter	ストレス	/sutoresu/	stress	maker
コイン	/koiN/	コイル	/koiru/	coil	リレー	/rireR/	relay	coin
バット	/baQto/	バッグ	/baQgu/	bag	スコア	/sukoa/	score	bat
タイル	/tairu/	タイヤ	/taija/	tire	マッチ	/maQcji/	match	tile
スパイ	/supai/	スパン	/supaN/	span	ルック	/ruQku/	look	spy
ブランド	/buraNdo/	ブラッド	/buraQdo/	blood	ピストル	/pisutoru/	pistol	brand
トランペット	/toraNpeQto/	トランジット	/toraNziQto/	transit	プロデュース	/purodjuRsu/	produce	trumpet
ベール	/beRru/	ベース	/beRsu/	base	ルアー	/ruaR/	lure	veil
ステーキ	/suteRki/	ステッキ	/suteQki/	stick	トランク	/toraNku/	trunk	stake
フォーク	/foRku/	フォーム	/foRmu/	form	アナログ	/anarogu/	analogue	fork
スケート	/sukeRto/	スケール	/sukeRru/	scale	ウイルス	/uirusu/	virus	skate
ショック	/sjoQku/	ショット	/sjoQto/	shot	リサーチ	/risaRcji/	research	shock
テント	/teNto/	テンポ	/teNpo/	tempo	プラス	/purasu/	plus	tent
ピン	/piN/	ピル	/piru/	pill	カー	/kaR/	car	pin
レンズ	/reNzu/	レンジ	/reNzi/	range/stove	ビーチ	/biRcji/	beach	lens
ガム	/gamu/	ガス	/gasu/	gas	キー	/kiR/	key	gum

Appendix 1 (*Continued*)

Translation Prime		*Phonological Prime*			*Unrelated Prime*			*High-frequency Target*
ツリー	/turiR/	ツアー	/tuaR/	tour	プラン	/puraN/	plan	tree
ゴール	/goRru/	メール	/meRru/	mail	マイク	/maiku/	microphone	goal
ドレス	/doresu/	プレス	/puresu/	press	シェア	/sjea/	share	dress
テスト	/tesuto/	ロスト	/rosuto/	lost	ワゴン	/wagoN/	wagon	test
カップル	/kaQpuru/	アップル	/aQpuru/	apple	リタイア	/ritaia/	retire	couple
ワイド	/waido/	エイド	/eido/	aide	ルビー	/rubiR/	ruby	wide
ベッド	/beQdo/	キッド	/kiQdo/	kid	ボイス	/boisu/	voice	bed
ステージ	/suteRzi/	コテージ	/koteRzi/	cottage	オーバー	/oRbaR/	over	stage
ケア	/kea/	エア	/ea/	air	ヨガ	/joga/	yoga	care
テーブル	/teRburu/	マーブル	/maRburu/	marble	エンジン	/eNziN/	engine	table
ベスト	/besuto/	ペスト	/pesuto/	pesto	ニーズ	/niRzu/	needs	best
プレー	/pureR/	ベレー	/bereR/	beret	キット	/kiQto/	kit	play
サウンド	/sauNdo/	バウンド	/bauNdo/	bound	アイデア	/aidea/	idea	sound
タウン	/tauN/	ダウン	/dauN/	down	ベビー	/bebiR/	baby	town
サウス	/sausu/	マウス	/mausu/	mouse/mouth	カーブ	/kaRbu/	curve	south
ワード	/waRdo/	カード	/kaRdo/	card	リアル	/riaru/	real	word
エリア	/eria/	アリア	/aria/	aria	ネール	/neRru/	nail	area
ヤング	/jaNgu/	キング	/kiNgu/	king	ケージ	/keRzi/	cage	young
ナンバー	/naNbaR/	アンバー	/aNbaR/	amber	プラント	/puraNto/	plant	number
ノート	/noRto/	カート	/kaRto/	cart	バレエ	/baree/	ballet	note
プール	/puRru/	セール	/seRru/	sale	ランク	/raNku/	rank	pool
マインド	/maiNdo/	ウインド	/uiNdo/	wind	クレヨン	/kurejoN/	crayon	mind
サンプル	/saNpuru/	シンプル	/siNpuru/	simple	マイナー	/mainaR/	minor	sample
パート	/paRto/	ビート	/biRto/	beat	グラフ	/gurahu/	graph	part
コース	/koRsu/	ピース	/piRsu/	peace/piece	ノズル	/nozuru/	nozzle	course
トラブル	/toraburu/	シラブル	/siraburu/	syllable	ハンガー	/haNgaR/	hanger/hunger	trouble
サポート	/sapoRto/	リポート	/ripoRto/	report	オープン	/oRpuN/	open	support
ヘア	/hea/	ペア	/pea/	pair	バー	/baR/	bar	hair
バランス	/baraNsu/	トランス	/toraNsu/	trance	ハードル	/haRdoru/	hurdle	balance
ヒット	/hiQto/	セット	/seQto/	set	ハーフ	/haRhu/	half	hit
リスク	/risuku/	リーク	/riRku/	leak	チキン	/cjikiN/	chicken	risk
スポット	/supoQto/	スキット	/sukiQto/	skit	チェーン	/cjeRN/	chain	spot
カバー	/kabaR/	カヌー	/kanuR/	canoe	ジャズ	/zjazu/	jazz	cover

Appendix 1 (*Continued*)

Translation Prime		*Phonological Prime*			*Unrelated Prime*			*High-frequency Target*
チーフ	/cjiRhu/	チーク	/cjiRku/	cheek	タッチ	/taQcji/	touch	chief
フィルム	/firumu/	フォルム	/forumu/	form	ライバル	/raibaru/	rival	film
レース	/reRsu/	レタス	/retasu/	lettuce	ホルン	/horuN/	horn	race
シーズン	/siRzuN/	シチズン	/sicjizuN/	citizen	ブロック	/buroQku/	block	season
ダンス	/daNsu/	ダンプ	/daNpu/	dump	ページ	/peRzi/	page	dance
レコード	/rekoRdo/	レパード	/repaRdo/	leopard	オレンジ	/oreNzi/	orange	record
モラル	/moraru/	モール	/moRru/	mall	シェフ	/sjehu/	chief	moral
ショート	/sjoRto/	シュート	/sjuRto/	shoot	ベランダ	/beraNda/	veranda	short
パワー	/pawaR/	パター	/pataR/	putter	エース	/eRsu/	ace	power
コスト	/kosuto/	コート	/koRto/	coat	バナナ	/banana/	banana	cost
ボート	/boRto/	ボーイ	/boRi/	boy	シンク	/siNku/	sink	boat
バンク	/baNku/	バンド	/baNdo/	band	ドーム	/doRmu/	dorm	bank
リスト	/risuto/	リフト	/rihuto/	lift	ポップ	/poQpu/	pop	list
トレード	/toreRdo/	トレンド	/toreNdo/	trend	シナリオ	/sinario/	scenario	trade
シングル	/siNguru/	シンボル	/siNboru/	symbol	アシスト	/asisuto/	assist	single
ホープ	/hoRpu/	ホーン	/hoRN/	horn	ヒント	/hiNto/	hint	hope
グラウンド	/gurauNdo/	グラインド	/guraiNdo/	grind	ディベート	/dibeRto/	debate	ground
タイプ	/taipu/	タイム	/taimu/	time/thyme	アート	/aRto/	art	type
ブラック	/buraQku/	ブランク	/buraNku/	blank	エリート	/eriRto/	elite	black
ライン	/raiN/	ライフ	/raihu/	life	ゲーム	/geRmu/	game	line
ホーム	/hoRmu/	ホール	/hoRru/	hall/hole	ペット	/peQto/	pet	home
スピーチ	/supiRcji/	スピード	/supiRdo/	speed	ユーザー	/juRzaR/	user	speech
サイズ	/saizu/	サイン	/saiN/	sign	ネット	/neQto/	net	size
ワールド	/waRrudo/	ワイルド	/wairudo/	wild	コンテナ	/koNtena/	container	world
プレース	/pureRsu/	プレート	/pureRto/	plate	リベラル	/riberaru/	liberal	place
ハート	/haRto/	ハード	/haRdo/	hard	シェル	/sjeru/	shell	heart
ナイト	/naito/	ナイス	/naisu/	nice	シーン	/siRN/	scene	night