Processing Japanese-English cognates in two reading tasks

Cross-linguistic lexical effects in different-script bilingual reading are modulated by task

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Abstract (<300w)

Aims and Objectives/Purpose/Research Questions

Bilingual lexical processing is non-selective, which allows for activation of the non-target language, even when reading in a different script. However, while the influence of cross-script L1 lexical knowledge has been demonstrated in isolated word reading, it is unknown whether it survives in more natural reading tasks. We investigated whether cross-linguistic facilitation due to phonological similarity, semantic similarity, and L1 cognate frequency, is observed when different-script bilinguals read cognate words in their L2 in sentence context and in isolation.

Design/Methodology/Approach

Two tasks were conducted with the same Japanese-English bilinguals and target items: A self-paced English reading task with non-highlighted target items embedded in sentence context; and an English lexical decision task. A monolingual control group also completed both tasks.

Data and Analysis

108 cognate items were embedded in sentence context and read by 23 Japanese-English bilinguals and 23 English monolinguals for meaning comprehension. The same items were then responded to by the same participants in lexical decision. Linear mixed-effects models were used to investigate the impact of continuous measures of L1-L2 phonological and semantic similarity, L1 cognate frequency, and L2 proficiency, while controlling for L2 lexical characteristics.

Findings/Conclusions

Cross-linguistic phonological and semantic similarity, as well as cognate frequency, partially determined reading times of words in both tasks but only in bilingual, not monolingual, reading. These effects were modulated by task, revealing reduced cross-linguistic facilitation in sentence reading relative to lexical decision.

Originality

This is the first study to investigate different-script cognate processing in sentence context and compare it with isolated word reading.

Significance/Implications

Although bilinguals do not switch off their L1 during L2 reading, the type of task partially determines how cross-linguistic effects impact reading times. The degree of overlap of Japanese-English cognates is less influential in natural reading tasks compared to isolated word reading tasks.

Keywords

Bilingual lexical processing; bilingual mental lexicon; cognates; Japanese-English; sentence reading; self-paced reading

Cross-linguistic influence from the first language (L1) while reading in a second language (L2) is a well-attested phenomenon. At the lexical level, words that share form and meaning across languages, such as cognates and loanwords, provide a benefit in processing referred to in psycholinguistics as the *cognate facilitation effect*. Bilinguals process such words more quickly and accurately relative to noncognate controls in a wide range of tasks (e.g., Dijkstra, Miwa, Brummelhuis, Sappelli & Baayen, 2010; Costa, Caramazza & Sebastián-Gallés, 2000) and with a wide range of known languages, including those that share script, such as Dutch-English (e.g., Dijkstra et al., 2010), and those that do not, such as Hebrew-English (Gollan, Forster & Frost, 1997), Korean-English (Kim & Davis, 2003), Greek-English (Voga & Grainger, 2007), Arabic-Hebrew (Degani, Prior & Hajajra, 2018) and Chinese-English (Zhang, Wu, Zhou & Meng, 2019).

Most relevant to the present study is the cross-script advantage observed for cognates during Japanese-English bilinguals' lexical processing. Studies have found this advantage in picture naming (Allen & Conklin, 2013; Hoshino & Kroll, 2008) and lexical decision (Allen & Conklin, 2013; Miwa, Dijkstra, Bolger & Baayen, 2014). Studies utilizing the masked priming paradigm have also demonstrated cross-script priming effects with Japanese-English cognates (Allen, Conklin & van Heuven, 2015) and have shown a cognate masked priming advantage (Nakayama, Sears, Hino & Lupker, 2012, 2013; Lupker, Nakayama & Perea, 2015). For instance, Nakayama, Sears, Hino & Lupker (2012) found that responses to L2 English targets (e.g., GUIDE) were faster when preceded by L1 cognate primes (e.g., ガイド /gaido/ 'guide') than when preceded by unrelated primes. In addition, they showed that responses to the same target were faster when the prime was phonologically similar but unrelated in meaning (e.g., サイド /saido/ 'side') than when the prime was unrelated (also see Ando et al., 2015). Taken together, Nakayama and colleagues' results revealed that cross-linguistic phonological activation occurs in different-script languages (see also Peleg, Degani, Raziq & Taha, 2019, for Arabic-Hebrew bilinguals), but cross-linguistic activation is greater when both phonology and semantics are shared, as in the case of cognates.

The cross-script advantage of cognates is due to the twin attributes of phonological and semantic overlap, both of which have been shown to contribute fine-grained faciliatory effects in L2 reading. For instance, when Japanese-English cognates (e.g., *guide-ガイド*/gaido/) have a higher degree of phonological overlap, they generate a greater priming effect (Nakayama, Verdonschot, Sears & Lupker, 2014). Similar findings have also been found using bilinguals' ratings of phonological similarity outside of the masked priming paradigm, which indicate a quantifiable difference in cross-linguistic activation according to the degree of shared phonology (Allen & Conklin, 2013; Miwa et al., 2014). In addition, greater semantic overlap, again measured by bilinguals' ratings, has also been shown to facilitate recognition of cognates (Miwa et al., 2014) though this may be affected by stimulus composition (see Allen & Conklin, 2013).

Overall, these studies demonstrate that when reading words in a different-script L2, the other language is not 'switched off' automatically but continues to influence the word recognition process. An important and unresearched issue is whether these cross-linguistic effects are observed in more 'natural' tasks, such as when reading sentences for general comprehension.

For same-script bilinguals, cognate words are typically processed more quickly than noncognates during L2 reading in sentence contexts (e.g., Bultena, Dijkstra & van Hell, 2014, 2015; Dijkstra, van Hell & Brenders, 2015; Van Assche, Duyck & Brysbaert, 2013; see van Assche, Duyck & Brysbaert, 2012, for a review; and Lauro & Schwartz, 2017, for a meta-analysis) and in longer texts (Balling, 2013; Cop, Dirix, Van Assche, Drieghe, & Duyck, 2017). This cross-linguistic facilitation tends to be greater when the sentence provides only minimal semantic context (i.e., low-constraint sentences) than when the sentence provides richer context (i.e., high-constraint sentences) (e.g., Duyck et al., 2007; Libben & Titone, 2009; Schwartz & Kroll, 2006; Van Hell & De Groot, 2008). Moreover, at the fine-grained level, same-script studies have shown that cognates with higher orthographic overlap are typically responded to more quickly in sentence reading (Bultena et al., 2014; Duyck et al. 2007; Van Assche et al., 2009, 2011). For instance, Bultena et al. (2014) used two different paradigms, self-paced sentence reading and sentence reading while eye-movements were recorded, and found orthographic similarity to be a significant predictor of reading times in both tasks.

For different-script bilinguals, no study has yet investigated whether cross-linguistic lexical facilitation occurs when reading sentences. This issue is important because it concerns whether phonological and semantic similarity alone (i.e., without shared orthography) are sufficient for a cognate effect to emerge when words are presented in context. According to the BIA+ model (Dijkstra & van Heuven, 2002) both of a bilingual's languages are activated regardless of whether they have same or different scripts. The BIA+ predicts an additive role of phonology and some support for this comes from same-script cognate studies (e.g., Dijkstra et al., 2010; Schwartz, Kroll & Diaz, 2007). However, researchers have struggled to disentangle continuous measures of form overlap (orthography and phonology) because they are typically highly correlated (e.g., $r = .94$, Dijkstra et al., 2010; Van Assche et al., 2011) and thus may be confounded. Utilizing different-script languages presents a way around this issue, allowing us to investigate the theoretically important and open question of whether phonological facilitation persists in a sentence context.

The present study

The aim of the present study is to assess whether cross-linguistic features in different-script languages influence L2 word reading when target words are presented within a sentence context. To this end, we conducted a self-paced reading study with Japanese-English bilinguals who read English sentences containing a target word that shared some degree of form and meaning across languages. To determine the magnitude of any cross-linguistic effects in the self-paced reading task, the same participants completed an L2 lexical decision task with the same target words and their response times were directly compared across the two tasks. Furthermore, to investigate the impact of cross-linguistic similarity at a fine-grained level, we focused exclusively on Japanese-English cognates and adopted a multi-trait, gradient definition including three indices: *phonological similarity*, *semantic similarity*, and *cognate freque*ncy. This approach is based on previous studies (e.g., Dijkstra et al., 2010; Miwa et al., 2014) and allows for investigation of the contributions of each aspect of cross-linguistic lexical facilitation. That is, rather than adopting a dichotomous factor of cognate/noncognate, we assume that cross-linguistic facilitation is not an all-or-nothing effect but one of degree. Crucially, this degree of facilitation is expected to vary according to lexical properties even when *all* target items share some degree of form and meaning. Finally, to determine whether the effects observed are unique to bilingual participants, we conducted a control experiment in which English-speaking monolinguals completed the same self-paced reading and lexical decision tasks.

Our predictions for the experiments are as follows: Firstly, measures of cross-linguistic lexical characteristics were expected to be significant only in the bilingual experiment. Secondly, based on previous studies and the predictions of the BIA+, we expected to see faciliatory effects of all cross-linguistic predictors in lexical decision. We also expected these effects in self-paced reading if the nature of the task allows sufficient time for cross-linguistic processing to impact reading times. However, it is also possible that null cross-linguistic effects are observed due to relatively slow activation of the overlapping phonological codes required for cross-linguistic facilitation in different-script languages. More precisely, this would occur because the context provides cues that speed lexical access and because sentence reading typically does not require responses to target words, which allows the reader to move quickly to the next word. In addition, we expect that the degree of semantic similarity may be of less relevance because the provision of context will allow the bilingual reader to access the L2 meaning quickly and more accurately than in isolated word tasks, such as lexical decision. Finally, Japanese cognate frequency is expected to facilitate reading times if bilinguals activate L1 representations during contextualized reading. Taken together, the results will be informative for understanding whether cross-linguistic effects that are typically observed in isolated word reading persist in tasks that are more akin to real-life reading, that is, when participants read words in context for comprehension without their attention being drawn specifically to the target words under investigation. In the following sections we present the bilingual experiment which consisted of the self-paced reading and lexical decision tasks, followed by identical tasks conducted in the monolingual control experiment.

Method

Participants

Twenty-four native speakers of Japanese taking English courses at a Japanese university (all females, age M = 22.0, SD = 4.7) were paid for participating in the bilingual experiment. They had intermediate proficiency according to their self-ratings (M = 6.1, SD = 1.0, 1 = non-user, to 10 = native-like ability). In addition, prior to the experiment English proficiency was assessed using the *Vocabulary Size Test* (*VST*; Nation & Beglar, 2007), which is a widely-used measure of receptive lexical knowledge, and indicated participants were at a high intermediate level of lexical proficiency (M = 65.4 (out of 140), SD = 14.2) with an estimated English vocabulary size of 6540 words.

Twenty-four undergraduates (16 female, age M = 18.9, SD = 0.7) at a U.K. university who were native speakers of English and had no knowledge of Japanese participated in the monolingual control experiment for course credit.

No participants suffered from visual or reading difficulties. The materials, procedure and analysis described hereafter were the same in the bilingual and monolingual experiments.

Experimental stimuli

We initially selected 284 English nouns between 4 and 6 letters long used in Dijkstra et al. (2010). Each target word was then embedded in a low-constraint sentence preceded by *the* and followed by *and*. This was done to avoid predictability created by the preceding word (e.g., *a* or *an*) and to restrict the syntactical variety of the sentences thus allowing participants to focus on lexical content. Sentences were in the present or past tense and were of one of two basic structures, each of which had the conjunction *and* followed by either a noun or a verb (e.g., *I added the tomato and celery to the pot*, or *the dog ran to the alley and barked loudly*). Target words did not appear in any other sentences and the number of words before and after the target was between three and seven.

To confirm that the sentence stem prior to the target word did not allow prediction of the target word, thirteen native English speakers at a U.K. university completed an online sentence-completion task for course credit. Participants completed 284 sentence stems by adding a plausible word. Of all the sentences, 24 (8%) were completed using the target word by one participant or more (M = 2.0; SD = 1.1). Due to the small number, these items were retained and a predictor, *target word predictability* (number of target responses per item / total responses per item), was included in the self-paced reading analysis to statistically account for target word predictability.

The sentence completion study also revealed variation in the number of similar responses given following the sentences stems. For example, for the stem *we listened to the*, where the target was *story*, responses included *radio* and *music* four times each, and five other words, giving a total of seven different responses (i.e., word types). To account for this variation, the ratio of word types in the responses was calculated for each sentence (number of word types / the total number of responses), and this measure, *stem predictability*, was included in the self-paced reading task analysis.

From the initial 284 items, 108 were selected for analysis considering the semantic and phonological similarity of the English word and its Japanese loanword equivalent, and the frequency and familiarity of the loanword in Japanese (Appendix 1). Each selected item had the same contextual meaning in both languages and was not homonymous in Japanese (e.g., ダート/daato/ can refer to both *dirt* and *dart* in English and so was not included). To confirm the degree of semantic and formal overlap between English and Japanese cognate translations, 29 Japanese-English bilinguals (all female, aged between 19 and 21, *VST* M = 54, SD = 9.7) rated all Japanese-English cognate word pairs (e.g. テーブル-*table*) for semantic similarity and phonological similarity on a 7-point scale (1 = completely different, 7 = identical).

To be certain all items would be known in Japanese and thus potentially benefit from cross-linguistic facilitation, the loanword equivalent of each item had a minimum frequency of one occurrence per million words in Japanese according to the *Balanced Corpus of Contemporary Written Japanese* (BCCWJ; Maekawa et al., 2014; National Institute for Japanese Language and Linguistics, 2013) because previous research has suggested this to be a useful benchmark of whether the loanword will be known (Allen, 2019c). Moreover, we consulted a database of familiarity ratings for Japanese words (Amano & Kondo, 2003) and selected only items that were rated as reasonably familiar (i.e., mean rating >4.5 on a scale of 1-7). Finally, 29 participants from a similar population to those in the bilingual experiment confirmed their knowledge of the items: each item was reported known to an average of 99.5% (SD=2.0) and to at least 26 out of 29 of the respondents. Table 1 shows descriptive statistics of the items.

TABLE 1 HERE

Procedure for self-paced reading

Participants were tested on a Macintosh Desktop computer with a button box (Cedrus RB-740) using PsychoPy (v1.84.2; Peirce, 2007). Stimuli were presented in courier

18 pts lowercase black letters in the center of a white screen, aligned to the left so that each sentence could be presented on a single line.

The self-paced sentence-reading task resembled that of Bultena et al. (2014). Participants read a sentence presented from left to right beginning with an asterisk. Participants pushed a button to see each word (Figure 1) and reading times were measured as the duration between two button presses. After a quarter of the trials, participants answered a yes/no comprehension question to ensure that they read the sentences for meaning. The experiment was conducted in four blocks with a break after each and four practice trials began each block. Instructions were provided in English and participants used their dominant hand during the task. The task took around 30 minutes to complete.

FIGURE 1 HERE

The same participants completed a lexical decision task with the same items used in the self-paced reading task. In addition, 284 nonwords were selected from the English Lexicon database (Balota, et al., 2007), matched to the target items on length and orthographic neighbourhood size (p's>.3). The equipment used was the same as that in the sentence reading task. Stimuli were presented in courier 18 pts lowercase black letters in the centre of a white screen. Instructions were provided in English at the beginning asking participants to decide as quickly and accurately as possible whether what appeared on the screen was an English word or not. Participants used their dominant hand for 'Yes' responses.

Each trial began with a fixation for 800ms, followed by a blank screen of 300ms prior to the stimulus which was presented for 1500ms or until a response was made. A 10-trial practice session preceded the task, in which participants were shown the accuracy and response time following each trial. The experiment was performed in four blocks with a break after each block. Three dummy items were presented at the beginning of each block. Items were presented pseudo-randomly with no more than five of either item type presented consecutively. The task took around 15 minutes to complete. Following the lexical decision task participants completed a brief language history questionnaire.

Predictors and Analyses

Cross-linguistic predictors included *semantic similarity* and *phonological similarity*, which were derived from the mean scores of the ratings described above, and *Japanese cognate frequency*, which was the BCCWJ frequency of the Japanese cognate translation transformed to log(frequency + 1). In addition, bilingual participants' accuracy (%) on the *Vocabulary Size Test* was used as a measure of their *L2 proficienc*y.

English language control predictors were included in the analyses to account for variance in the items that was not related to cross-linguistic factors: (Log-transformed) *English word frequency* ($SUBTLEX_{US}$; Brysbaert & New, 2009), *word length*, *orthographic Levenshtein distance* (Yarkoni, Balota & Yap, 2008), and *concreteness* (Brysbaert, Warriner & Kuperman, 2014). In addition, *Trial* number was included to measure any practice or fatigue effects.

Some of the above predictors were naturally correlated and so were residualized. This involved fitting a linear model for a predictor and its correlated predictor, and extracting the residuals of this model for use in the analysis (see Miwa et al., 2014). All predictors were scaled for the analyses.

Finally, to investigate the impact of cross-linguistic effects in contextualized and isolated word reading, data from both tasks were combined and *task* was added as a factor to the model. Interactions between this factor and other predictors would indicate significant differences in processing effects in the two task types.

Analyses were conducted in R version 3.0.2 (R Core Development Team, 2013) using the function *lmer* in the package *lme4* (version 1.1-7; Bates, Maechler, Bolker & Walker, 2015). Reading times were transformed for the analysis (-1000/RT). All predictors and the two-way interactions between them were added to a model with random intercepts for subjects and items. The model was backward-simplified automatically using the *step* function in *lmerTest* (version 2.0-20, Kuznetsova, Brockhoff & Christensen, 2017), which applies log-likelihood testing by first removing non-significant interactions then main effects. Following this, by-subject random slopes for all main effects (and a by-item random slope for *L2 proficiency* in the bilingual analysis) were added successively and maintained if they significantly improved the model. To increase the reliability and replicability of the findings, alpha was set at .01 during the modelling process.

Results

Bilingual experiment

Participants responded accurately to comprehension questions during the self-paced reading task (accuracy *M* = 84.0%, *SD* = 7.0%), though one participant had below 75% accuracy overall and was thus removed, leaving 23 participants in the analysis. This high accuracy threshold was used because we wanted to be sure that participants were sufficiently comprehending the sentences. Following visual inspection, outlier cut-off points were determined. Responses of <150ms and >2000ms were removed (2.4% of data) leaving 2419 trials in the bilingual self-paced reading analysis. The lexical decision analysis consisted of the same 23 participants, whose mean item response accuracy was 94.2% (SD=3.2%). Two items had overall accuracy rates of below 70% and were removed, leaving 106 items in the analysis. Responses below 150ms or above 1500ms (1.1% of data) and inaccurate responses (3.2% of data) were removed, leaving 2378 trials in the bilingual lexical decision analysis. The total number of trials in bilingual combined analysis was 4797.

Table 2 shows the final model for the bilingual data. *Task* was highly significant and revealed that response times were much faster in the self-paced reading task than in lexical decision. (i.e., M = 557ms, SD = 306ms; and M = 625ms, SD = 166ms, respectively). Moreover, *task* interacted with *trial* showing how participants' reading sped up dramatically over the course of the self-paced reading experiment (Figure 2). In addition, the significant effect of *L2 proficiency* shows that participants with higher proficiency responded more quickly to items in both tasks than those with lower proficiency.

All of the cross-linguistic predictors (*phonological similarity*, *semantic similarity,* and *Japanese cognate frequency*) were significant and faciliatory in the combined model. In addition, an interaction between *semantic similarity* and *task* reveals that the effect of *semantic similarity* occurred only in lexical decision (Figure 3). In contrast, the absence of interactions between *task* and the other cross-linguistic predictors suggests they had similar faciliatory effects in both tasks. However, inspection of individual models (Appendix 2) reveals a more complex picture: *phonological similarity* was significant as a main effect but only in lexical decision, whereas *Japanese cognate frequency* was not significant as a main effect in either model; however, both predictors featured in the interactions discussed below.

Table 2 and Figure 4 show that *Japanese cognate frequency* mediated the effects of *phonological similarity* and *L2 proficiency.* That is, when the English words had lower frequency cognates in Japanese, the faciliatory effects of *phonological similarity* and *L2 proficiency* were greatest. In contrast, English words with higher frequency cognates in Japanese were not facilitated by these variables, especially in the case of *phonological similarity*. Inspection of separate models revealed that these interactions were significant only in self-paced reading.

Regarding English-language control predictors, there was a strong and faciliatory effect of *English word frequency*. Inhibitory effects of *length* and *orthographic Levenshtein distance* were observed and these effects both reduced over the course of the experiment as indicated by the interactions with *trial*. Finally, *concreteness* was significant, showing items that were more abstract tended to be read and responded to more quickly. Inspection of individual models shows that this effect arose primarily in the self-paced reading task.

TABLE 2 HERE

FIGURES 2, 3, AND 4 HERE

Monolingual experiment

One participant had less than 75% accuracy on the responses to the comprehension questions in the monolingual self-paced reading task and so was removed, leaving 23 participants. The remaining participants' responses were highly accurate, showing they were reading for comprehension (accuracy M = 95.4%, SD = 4.3%). Outlier responses of <150ms and >2000ms were removed (1.6% of data) leaving 2440 trials. The same 23 participants were included in the monolingual lexical decision analysis, for which they had a mean accuracy of 96.9% (SD = 0.03%). No items had accuracy rates of below 70%. Responses below 150ms or above 1500ms (0.4% of data) and inaccurate responses (2.3% of data) were removed, leaving 2419 trials in the following analyses. The total number of trials in monolingual combined analysis was 4859.

Table 3 shows the final model for the monolingual data. There was a significant difference between the speed of responses between the two tasks, with response speed for self-paced reading being markedly faster. The average response time was 320ms (SD = 125ms) in self-paced reading and 555ms (SD = 209) in lexical decision. Moreover, as in bilingual self-paced reading, an interaction between *task* and *trial* shows that response times significantly decreased over time. There was an expected *English word frequency* effect, as observed in bilingual reading. Finally, *concreteness* interacted with task revealing that it had a greater effect in self-paced reading and, as in the bilingual experiment, more abstract words were read more quickly.

Inspection of separate models for each task reveals that *trial* was significant in both tasks but the size of the effect was many magnitudes greater in self-paced reading. In fact, due to the speed of monolingual self-paced reading, other than *trial* no predictors remained in the final model. In contrast, the final model for lexical decision included *English word frequency* as well as interactions between *trial* and *length*, and *trial* and *orthographic neighborhood distance*, both of which showed inhibitory effects that were greater at the beginning of the experiment but attenuated over time.

TABLE 3 HERE

Discussion

The present study examined whether cross-linguistic lexical effects emerge in sentence reading and in isolated word reading for different-script cognates, and additionally whether such effects were present in the same tasks with monolinguals. The findings demonstrate that significant effects of phonological and semantic similarity, and cognate frequency, were present in the bilingual experiment but absent from an identical monolingual experiment. This provides evidence that these measures reflect aspects of bilingual lexical processing, rather than capturing aspects of generic lexical processing or the properties of the words in English. Moreover, the findings support the non-selective view of lexical access, that is, when bilinguals read in the L2, lexical access is implicitly influenced by L1 lexical knowledge even when no overt L1 cues are present in the task.

Our study is the first to examine cross-linguistic effects in sentence reading with bilinguals whose languages differ in script. We specifically investigated the role of individual cross-linguistic predictors that make up the ‘cognate facilitation effect’ rather than comparing reading times for cognates and noncognates. By analyzing reading times for cognates in bilingual sentence reading and lexical decision, we show

how the type of task used partially determined the extent to which these cross-linguistic features impact bilingual lexical processing.

Phonological similarity between English words and their Japanese loanword counterparts significantly predicted reading times in both bilingual experiments. Thus, phonological overlap is sufficient to manifest an advantage in processing in the absence of shared orthography, which supports the findings with different-script bilinguals in general (e.g., Gollan, Forster & Frost, 1997; Kim & Davis, 2003; Voga & Grainger, 2007) and with Japanese-English bilinguals specifically (Allen & Conklin, 2013; Miwa et al., 2014).

Phonological similarity was faciliatory as a main effect in lexical decision, while in self-paced reading it was faciliatory only for words that had low-frequency L1-cognates and which therefore were processed more slowly (i.e., in comparison to words with high-frequency L1-cognates; Japanese cognate frequency is discussed in more detail below). These findings suggest that, when orthographic cues are absent, facilitation based on cross-linguistic formal similarity is evident but reduced when word reading is fast (i.e., in contextualized word reading).

Overall, the finding that sentence context did not completely eliminate cross-linguistic activation of phonology supports the predictions of the BIA+, which assumes non-selective activation of lexical candidates during both isolated and contextualized word recognition. The BIA+ holds that language membership (i.e., the language of the sentence) does not create language-selective processing, as assumed in the earlier BIA model (Van Heuven, Dijkstra & Grainger, 1998) and in alternative theories of bilingual lexical processing (e.g., Grosjean, 1997). However, as assumed in the BIA+, task demands appear to be crucial in determining whether bilingual effects are observed in reading times. That is, the difference in impact of cross-linguistic features appears to depend on the speed at which participants read words and the type of response that they are required to produce.

The reduced impact of phonological similarity may be due to the time required to access phonological information in the L1 during L2 reading: in same-script language reading, orthographic cues are processed initially, leading to immediate L2-L1 cross-linguistic activation at the sub-lexical and lexical orthographic levels. This activation accounts for the significant orthographic similarity effects observed in same-script sentence-reading studies (e.g., Bultena et al., 2014; Cop et al., 2017; Van Assche et al., 2009, 2011; but see Experiment 3 in Duyck et al., 2007). In different-script bilingual reading, L2-L1 cross-linguistic activation is initially via cross-linguistic activation of phonology, which occurs after orthographic processing in the L2. This delay in activation may explain why we observed much reduced effects of cross-linguistic phonological overlap in sentence reading.

Another important finding was observed in the role of semantic similarity in the two tasks. In the combined bilingual model, and in lexical decision specifically, semantic similarity between English and Japanese words was shown to significantly facilitate response times. That is, words which overlap more across languages in terms of their conceptual representations were recognized more quickly by bilinguals reading in a second language. This is consistent with previous research with Japanese-English bilinguals (Miwa et al., 2014) and with the predictions of the BIA+ (Dijkstra & van Heuven, 2002), which assumes that the degree of facilitation is proportional to the degree of overlap in semantic features of the cognate. However, the absence of this effect in sentence reading points to the role of context: When participants read words embedded in context, even a non-constraining context as provided in the present study, sufficient cues to word meaning are provided in the L2 rendering the similarity to L1 concepts ineffectual in speeding reading times.

In addition to the availability of context, word reading times in bilingual self-paced reading were fast, which is likely to play a role in the null effect of cross-linguistic semantic similarity. Although the L1 semantic features are expected to become activated via shared connections across languages, and via feedback mechanisms between lexical and sub-lexical representations as postulated in the BIA+, lexical access during L2 sentence reading proceeds so quickly that L1-L2 semantic similarity may have no observable impact on word reading times.

Importantly, all of the English words and their loanword equivalents were contextually appropriate. In a different situation where the L1 cognate meaning conflicts with the contextual meaning in the L2 sentence, a measurable delay in processing may be observed (for instance, see the findings for false-cognate processing in a semantic-relatedness task with Arabic-Hebrew bilinguals in Degani et al., 2018). However, given that there were no overt (i.e., orthographic) cues to the L1 in the task, it is also plausible that L2 context supports L2 reading sufficiently to override any such interference. Future research using L2 words with contextually inappropriate L1-meanings (i.e., false-cognates) is necessary to investigate this issue.

The third cross-linguistic measure, Japanese cognate frequency, was notably less prominent in both bilingual tasks compared to previous studies. This measure is assumed to reflect the resting level of activation of the lexical representation in the L1 and thus reflects how well the cognates are likely to be known in the L1. In studies with Japanese-English bilinguals, it has been shown to predict response times in lexical decision (Miwa et al., 2014) and accuracy on tests of lexical knowledge (Allen, 2019a, 2019b). In the present study, however, cognate frequency played a more specific role in that it modulated effects of phonological similarity and L2 proficiency during sentence reading, while it did not influence processing in lexical decision. In contextualized reading, when cognates were higher frequency, they were less likely to receive additional facilitation in the form of phonological similarity. This suggests that processing for these words in self-paced reading was already at ceiling. Moreover, responses by participants with lower L2 proficiency were facilitated by higher Japanese cognate frequency, most likely because their responses were slower overall, which allowed for L1 cognate knowledge to play a more significant role. Although we initially expected cognate frequency to play a more important role in modulating bilingual lexical processing in lexical decision, its reduced role overall may be explained by the fact that all English words had relatively high-frequency cognates in Japanese, whereas in previous studies English words with cognates of a greater range of frequency were included (as well as noncognates which had a frequency of zero). Studies using items with a greater range of cognate frequency would be expected to demonstrate a faciliatory role of cognate frequency.

Limitations

This is the first study to investigate cross-linguistic effects in different-script languages when reading words in context. However, more research is needed to explore these effects in a wider range of conditions and circumstances. Importantly, we observed minimal cross-linguistic effects with semantically low-constraint sentences (i.e., ones in which the target word not was predictable). Cross-linguistic effects are expected to be further diminished in high-constraint sentences, which provide strong contextual cues to the specific target word in the L2 and thus further speed up lexical access (see Lauro & Schwartz, 2017). Also, it is unclear whether cross-linguistic effects would emerge with other different-script bilinguals (e.g., Hebrew-English) or with bilinguals of lower/higher L2 proficiency, in tasks where reading may be even faster (i.e. with eye-tracking), or when using target words other than nouns (see e.g., Bultena et al., 2014). With the aim of moving towards a more comprehensive model of bilingual lexical processing, future studies will need to clarify the impact of these conditions upon cross-linguistic effects in different-script languages.

Conclusions

It was demonstrated that a difference in script does not eliminate cross-linguistic effects when bilinguals read words in sentences and in isolation. This is the first study to show the impact of cross-linguistic lexical similarity with etymologically unrelated and orthographically distinct languages when bilinguals read sentences for meaning. Notably, our findings indicate that these cross-linguistic effects are reduced in more 'natural' reading tasks, such as sentence reading. Although this conclusion applies most directly to Japanese-English bilinguals reading in their L2 (English), it may also extend to readers in other bilingual populations. The implication is that while bilinguals do not switch off their L1 during L2 reading, the type of task considerably affects whether cross-linguistic effects are observed and whether these impact reading times. Finally, while previous research has typically focused on 'cognates' and 'noncognates', this study emphasizes the importance of focusing on the distinct elements of the 'cognate effect', that is, the distinct roles of formal and semantic similarity.

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Table 1: *Descriptive statistics for items used in the analyses*

	Mean (SD)	Range	Median (IQR)
Phonological similarity	5.4 (0.5)	3.9 – 6.2	5.5 (0.7)
Semantic similarity	6.3 (0.5)	3.9 – 6.7	6.4 (0.7)
Japanese cognate frequency (log- transformed)	6.9 (1.1)	4.7 – 9.7	6.9 (1.6)
English word frequency (log-transformed)	3.3 (0.6)	2.2 – 4.8	3.2 (0.7)
Length	5.0 (0.8)	4 – 6	5.0 (2.0)
Orthographic Levenshtein distance	1.8 (0.4)	1.0 – 3.3	1.8 (0.5)
Concreteness	4.2 (0.9)	1.3 – 5.0	4.7 (1.2)
L2 proficiency (VST%)	46.1 (9.5)	33.6 – 68.6	42.1 (5.0)

Table 2. *Results of the mixed-effects model for bilingual self-paced reading and lexical decision.*

Random effects			
Groups	Name	Variance	SD
Item	*(Intercept)*	0.008	0.090
Participant	*(Intercept)*	0.030	0.172
	Task	0.419	0.648

Fixed Effects				
Name	*β**	*SE*	*t*	*p*
Intercept	0.353	0.041	8.699	<.001
Task	-0.879	0.137	-6.380	<.001
Phonological similarity	-0.044	0.014	-3.065	<.01
Semantic similarity	-0.064	0.018	-3.586	<.001
English word frequency	-0.133	0.015	-8.655	<.001
Japanese cognate frequency	-0.037	0.014	-2.600	<.05
L2 proficiency	-0.189	0.039	-4.886	<.001
Trial	-0.013	0.015	-0.904	0.366
Length	0.128	0.020	6.370	<.001
Orthographic Levenshtein distance	0.095	0.021	4.565	<.001
Concreteness	0.046	0.015	3.210	<.01
*Task*Semantic similarity*	0.070	0.021	3.310	<.001
*Task*Trial*	-0.367	0.034	-10.759	<.001
*Phonological similarity*Japanese cognate frequency*	0.056	0.015	3.696	<.001
Japanese cognate frequency L2 proficiency*	0.032	0.011	3.061	<.01
*Trial*Length*	-0.055	0.015	-3.574	<.001
Trial Orthographic Levenshtein distance*	-0.049	0.016	-3.080	<.01

* β is the standardized model coefficient created by scaling the response variable and numerical predictors; Pseudo R^2 (fixed effects) = 0.20; Pseudo R^2 (total) = 0.45; AIC = 8434.

Table 3. *Results of the mixed-effects model for monolingual self-paced reading and lexical decision.*

Random effects			
Groups	Name	Variance	SD
Item	*(Intercept)*	0.005	0.071
Participant	*(Intercept)*	0.054	0.231
	Task	0.597	0.773
	Trial	0.006	0.067

Fixed Effects				
Name	*β**	*SE*	*t*	*p*
Intercept	0.673	0.050	13.468	<.001
Task	-1.731	0.162	-10.683	<.001
English word frequency	-0.037	0.010	-3.749	<.001
Trial	-0.029	0.017	-1.699	.101
Concreteness	-0.007	0.012	-0.559	.576
*Task*Concreteness*	0.049	0.015	3.379	<.001
*Task*Trial*	-0.765	0.023	-33.746	<.001

*β is the standardized model coefficient created by scaling the response variable and the numerical predictors; Pseudo R^2 (fixed effects) = 0.51; Pseudo R^2 (total) = 0.78; AIC = 9030.

Figure 1: Stimulus presentation in self-paced reading

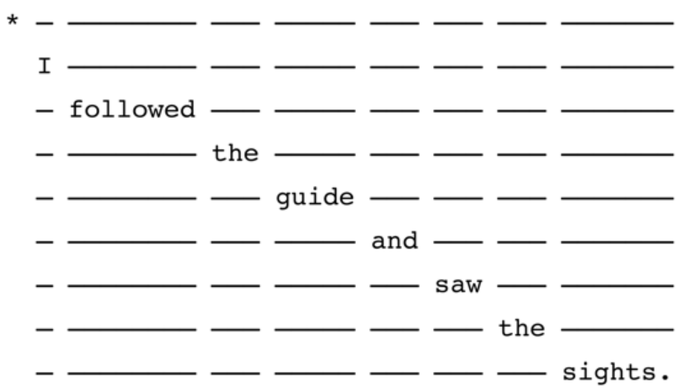


Figure 2: Semantic similarity effect by task in the bilingual experiment

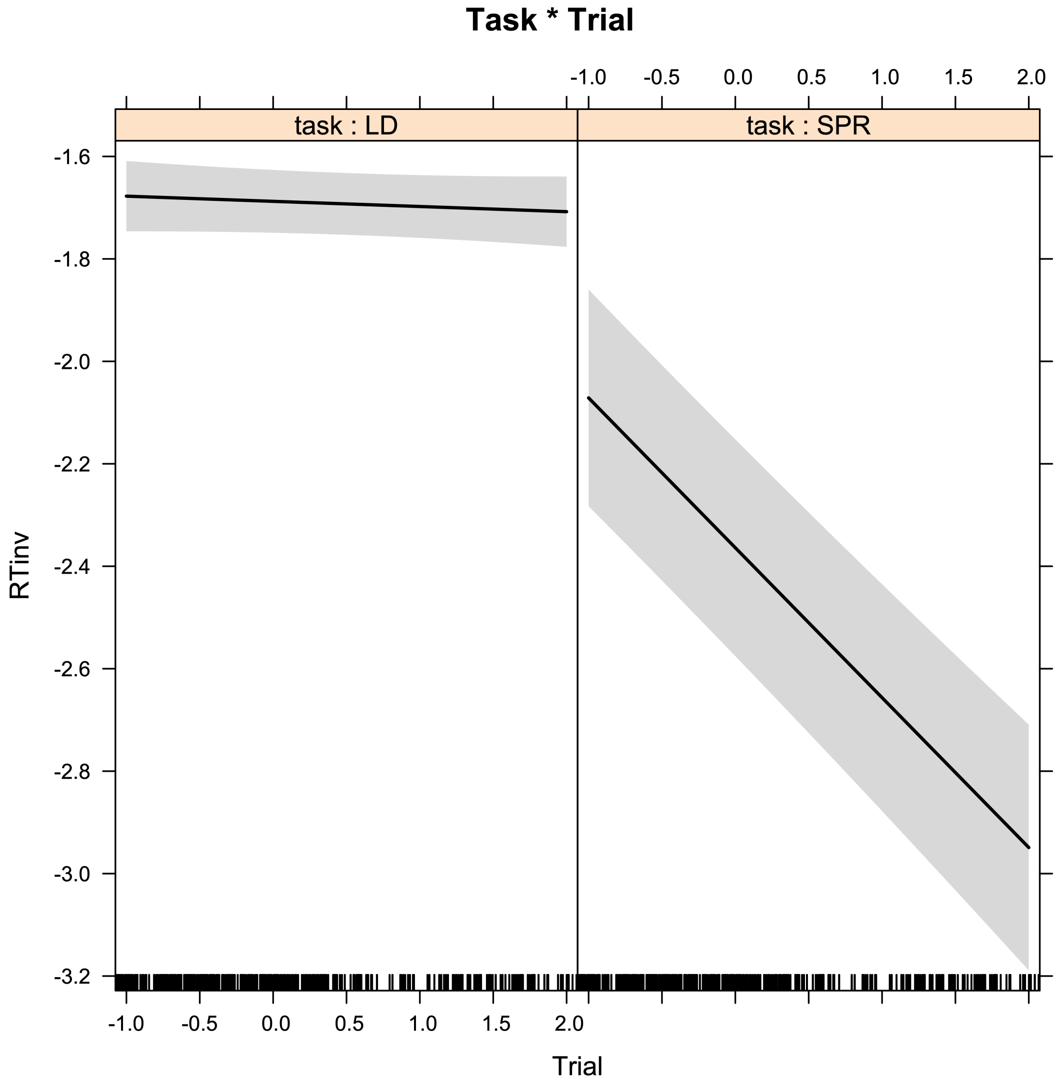


Figure 3: Trial effect by task in the bilingual experiment

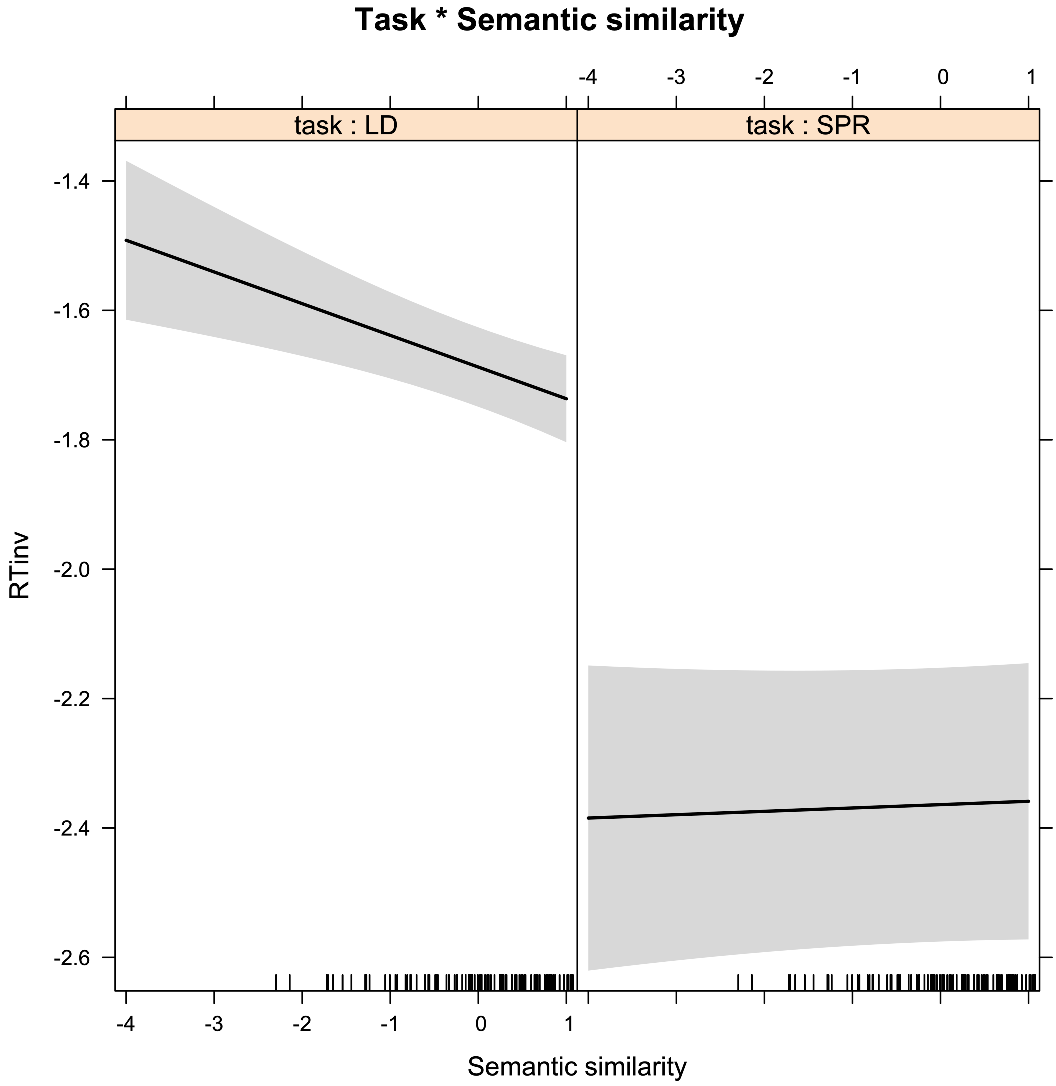
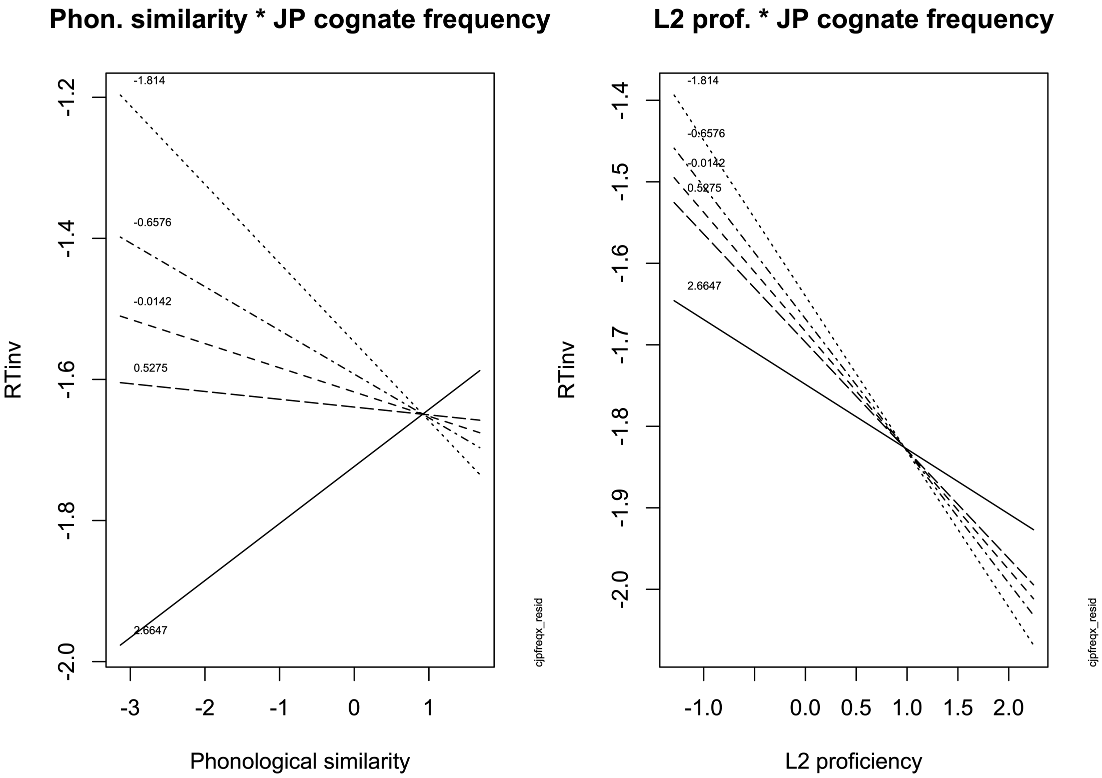


Figure 4: Interactions of phonological similarity and L2 proficiency with Japanese cognate frequency in the bilingual experiment



Appendix 1: *Items and sentence contexts used in experiments*

*Japanese cognate translations were acquired from the *Balanced Corpus of Contemporary Written Japanese* (Maekawa et al., 2014; National Institute for Japanese Language and Linguistics, 2013). ** Japanese Romanized form is written using the Hepburn system though for simplicity we do not use macrons for the extended vowels and instead double the preceding vowel to show lengthening (e.g., *peace*, ピース, piisu).

	English target item	**Japanese cognate translation***	**Japanese Romanized form****	**sentence context**
1	chaos	カオス	kaosu	They tried to escape the chaos and brutality of war
2	moment	モーメント	moomento	I will never forget the moment and often recall it
3	roof	ルーフ	ruufu	The cat climbed to the roof and would not come down
4	detail	ディテール	diteeru	They were amazed at the detail and quality of the work
5	fire	ファイア	faia	We could see the fire and called for help
6	plant	プラント	puranto	She lifted the plant and put it in the sunlight
7	seed	シード	shiido	The sunlight warmed the seed and it sprouted
8	trace	トレース	toreesu	We could see the trace and copied it
9	wind	ウインド	uindo	I really dislike the wind and hail on this island
10	pill	ピル	piru	She took the pill and felt better
11	wing	ウイング	uingu	The flames began on the wing and spread from there
12	metal	メタル	metaru	The buyers looked up at the metal and concrete structure
13	saddle	サドル	sadoru	I got into the saddle and turned the throttle
14	angle	アングル	anguru	It was the angle and pressure that made him miss
15	head	ヘッド	heddo	Remove the head and the scales of the fish
16	hope	ホープ	hoopu	It was for the hope and glory of victory
17	candy	キャンデー	kyandee	The children devoured the candy and pleaded for more
18	chair	チェア	chea	The teacher walked to the chair and sat down
19	plate	プレート	pureeto	The child threw the plate and it smashed
20	echo	エコー	ekoo	The audience could hear the echo and feedback from the speakers
21	noise	ノイズ	noizu	The passengers were surprised by the noise and commotion
22	virgin	バージン	baajin	The children looked at the virgin and child picture in amazement
23	tenant	テナント	tenanto	She called the tenant and insisted that he pay up
24	paint	ペイント	peinto	They bought the paint and the brushes
25	mail	メール	meeru	I went out to collect the mail and buy some tea
26	watch	ウォッチ	uocchi	I looked at the watch and dreamed I could buy it
27	target	ターゲット	taagetto	They saw the target and fired
28	gate	ゲート	geeto	We rushed to the gate and barely caught the flight
29	girl	ガール	gaaru	The parcel was delivered to the girl and her family
30	prince	プリンス	purinsu	It was the ceremony of the prince and princess' engagement
31	loss	ロス	rosu	He ignored the loss and invested again
32	angel	エンジェル	enjeru	The filmakers wanted the angel and demon film to be a hit
33	total	トータル	tootaru	I looked at the total and almost fainted
34	king	キング	kingu	The soldiers met the king and received a medal
35	chain	チェーン	cheen	The old lady put on the chain and looked out through the door

36	monkey	モンキー	monkii	It was about the monkey and the coconut
37	rail	レール	reeru	Take the rail and walk carefully
38	woman	ウーマン	uuman	The police arrested the woman and charged her
39	cherry	チェリー	cherii	The squirrels picked at the cherry and fought over it
40	summer	サマー	samaa	The teachers awaited the summer and other vacations
41	desk	デスク	desuku	The clerk stood at the desk and sighed
42	anchor	アンカー	ankaa	The men raised the anchor and set sail
43	sugar	シュガー	shugaa	I asked for the sugar and a spoon
44	napkin	ナプキン	napukin	The elderly man dropped the napkin and struggled to retrieve it
45	bottle	ボトル	botoru	The sailors caught the bottle and read the letter inside
46	ring	リング	ringu	He decided to buy the ring and propose to her
47	sock	ソックス	sokkusu	Mother picked up the sock and asked whose it was
48	mirror	ミラー	miraa	She peered into the mirror and didn't recognize herself
49	circle	サークル	saakuru	They formed the circle and sang together
50	rhythm	リズム	rizumu	Just keep the rhythm and dance
51	plan	プラン	puran	The engineers took the plan and built the bridge
52	garden	ガーデン	gaaden	The dog ran to the garden and barked loudly
53	error	エラー	eraa	I regretted the error and tried not to do it again
54	gold	ゴールド	goorudo	The banker took the gold and silver from the safe
55	bucket	バケツ	baketsu	The children left the bucket and spade at the shore
56	love	ラブ	rabu	There is nothing better than the love and affection of a cat
57	price	プライス	puraisu	I was not happy with the price and the service provided
58	shoe	シューズ	shuuzu	The stewardess held the shoe and wondered
59	coin	コイン	koin	The teenager found the coin and picked it up
60	silk	シルク	shiruku	The feel of the silk and its hue made him buy it
61	oven	オーブン	oobun	The gloves were on the oven and melted a little
62	school	スクール	sukuuru	He arrived at the school and went in
63	body	ボディー	bodii	It is good for the body and soul
64	case	ケース	keesu	The steward looked at the case and refused
65	model	モデル	moderu	The audience regarded the model and applauded her
66	joke	ジョーク	jooku	We did not understand the joke and felt embarrassed
67	doctor	ドクター	dokutaa	I went to see the doctor and got some medicine
68	money	マネー	manee	The man took the money and ran off
69	beach	ビーチ	biichi	The gulls landed on the beach and searched for crabs
70	screen	スクリーン	sukuriin	The assistant wiped the screen and started the computer
71	milk	ミルク	miruku	We left some of the milk and bread out for the cats
72	type	タイプ	taipu	The lady selected the type and quantity of flowers
73	water	ウォーター	uootaa	We looked out at the water and dreamed of sailing away
74	spoon	スプーン	supuun	The baby grabbed the spoon and threw it
75	fruit	フルーツ	furuutsu	The hawk flew to the fruit and pecked at it
76	knife	ナイフ	naifu	I picked up the knife and fork and began to eat
77	guide	ガイド	gaido	I followed the guide and saw the sights
78	skirt	スカート	sukaato	The customer returned the skirt and asked for a refund

79	tire	タイヤ	taiya	We fixed the tire and continued our journey
80	office	オフィス	ofisu	They cleaned up the office and took their leave
81	pants	パンツ	pantsu	The traveller unpacked the pants and pyjamas from his luggage
82	idea	アイディア	aidia	She had the idea and developed it thoroughly
83	pocket	ポケット	poketto	It was in the pocket and I didn't realize
84	guitar	ギター	gitaa	The youngster picked up the guitar and played a tune
85	mask	マスク	masuku	The boy wore the mask and pretended to be Dracula
86	soup	スープ	suupu	They had the soup and bread for lunch
87	card	カード	kaado	I forgot the card and went home to get it
88	melon	メロン	meron	The children carried the melon and then broke it up
89	circus	サーカス	saakasu	Everyone was excited about the circus and ran into town
90	tennis	テニス	tenisu	He was excited by the tennis and bought a racket
91	story	ストーリー	sutoorii	We listened to the story and thought about its meaning
92	advice	アドバイス	adobaisu	The son rejected the advice and suggestions of his parents
93	power	パワー	pawaa	He always desired the power and status of a politician
94	menu	メニュー	menyuu	He passed the menu and we ordered together
95	member	メンバー	menbaa	The secretary asked the member and then renewed his subscription
96	sport	スポーツ	supootsu	They saw the sport and drank beer
97	kiss	キス	kisu	I did not expect the kiss and was very embarrassed
98	point	ポイント	pointo	I did not see the point and gave up
99	banana	バナナ	banana	The assistant saw the banana and returned it to the shelf
100	design	デザイン	desain	I really like the design and feel of this sofa
101	lion	ライオン	raion	They were scared by the lion and stayed close together
102	cheese	チーズ	chiizu	We requested more of the cheese and biscuits
103	drama	ドラマ	dorama	I did not like the drama and so I turned it off
104	engine	エンジン	enjin	The mechanic said the engine and gearbox needed work
105	hotel	ホテル	hoteru	They decided to visit the hotel and check-in first
106	tomato	トマト	tomato	I added the tomato and celery to the pot
107	chance	チャンス	chansu	The employee got the chance and she took it
108	coffee	コーヒー	koohii	The gentleman brought the coffee and cake for us

Appendix 2: *Mixed-effects models for each task*

Table A1. *Results of the mixed-effects model for bilingual self-paced reading*.

Random effects			
Groups	Name	Variance	SD
Item	*(Intercept)*	0.005	0.072
	L2 proficiency	0.012	0.108
Participant	*(Intercept)*	0.272	0.522
	Trial	0.018	0.132

Fixed Effects				
Name	*β*	*SE*	*t*	*p*
Intercept	0.009	0.110	0.078	.938
Phonological similarity	-0.027	0.017	-1.563	0.121
English word frequency	-0.089	0.018	-4.782	<.001
Japanese cognate frequency	-0.035	0.018	-1.957	0.053
L2 proficiency	-0.278	0.107	-2.601	<.05
Trial	-0.164	0.032	-5.060	<.001
Length	0.147	0.026	5.978	<.001
Orthographic Levenshtein distance	0.109	0.025	4.322	<.001
Concreteness	0.043	0.018	2.410	<.05
*Phonological similarity*Japanese cognate frequency*	0.056	0.018	3.054	<.01
Japanese cognate frequency L2 proficiency*	0.043	0.019	2.304	<.05

**β* is the standardized model coefficient created by scaling the response variable and numerical predictors; Pseudo R^2 (fixed effects) = 0.12; Pseudo R^2 (total) = 0.43; AIC = 5551.

Table A2. *Results of the mixed-effects model for bilingual lexical decision*.

Random effects				
Groups	Name		Variance	SD
Item	*(Intercept)*		0.099	0.315
Participant	*(Intercept)*		0.146	0.382
	Length		0.005	0.072

Fixed Effects				
Name	*β*	*SE*	*t*	*p*
Intercept	0.004	0.087	0.047	.963
Phonological similarity	-0.118	0.035	-3.364	<.01
Semantic similarity	-0.151	0.034	-4.397	<.001
English word frequency	-0.282	0.036	-7.929	<.001
L2 proficiency	-0.354	0.077	-4.630	<.001
Trial	-0.025	0.019	-1.270	0.204
Length	0.169	0.051	3.341	<.01
Orthographic Levenshtein distance	0.126	0.050	2.513	<.05
*L2 proficiency*Trial*	0.042	0.015	2.748	<.01
*Trial*Length*	-0.072	0.027	-2.701	<.01
Trial Orthographic Levenshtein distance*	-0.071	0.025	-2.861	<.01

**β* is the standardized model coefficient created by scaling the response variable and numerical predictors; Pseudo R^2 (fixed effects) = 0.23; Pseudo R^2 (total) = 0.48; AIC = 872.

Table A3. *Results of the mixed-effects model for monolingual self-paced reading.*

Random effects					
Groups	Name			Variance	SD
Item	*(Intercept)*			0.018	0.136
Participant	*(Intercept)*			0.467	0.683
	Trial			0.032	0.177
Fixed Effects					
Name		*β*	*SE*	*t*	*p*
Intercept		-0.010	0.144	-0.072	.944
Trial		-0.411	0.040	-10.296	<.001

**β* is the standardized model coefficient created by scaling the response variable and numerical predictors; Pseudo R^2 (fixed effects) = 0.17; Pseudo R^2 (total) = 0.67; AIC = 5533.

Table A4. *Results of the mixed-effects model for monolingual lexical decision*.

Random effects					
Groups	Name			Variance	SD
Item	*(Intercept)*			0.064	0.254
Participant	*(Intercept)*			0.353	0.594
	English word frequency			0.007	0.081
	Trial			0.015	0.120
Fixed Effects					
Name		*β*	*SE*	*t*	*p*
Intercept		-0.008	0.127	-0.061	.952
English word frequency		-0.094	0.034	-2.756	<.01
Trial		-0.069	0.032	-2.185	<.05
Length		0.010	0.041	0.240	0.811
Orthographic Levenshtein distance		0.028	0.042	0.656	0.513
*Trial*Length*		-0.072	0.027	-2.689	<.01
Trial Orthographic Levenshtein distance*		-0.095	0.026	-3.680	<.001

**β* is the standardized model coefficient created by scaling the response variable and numerical predictors; Pseudo R^2 (fixed effects) = 0.02; Pseudo R^2 (total) = 0.45; AIC = 2209.