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Is There Lexical Competition in the Recognition of L2 Words for Different-Script Bilinguals? An Examination Using Masked Priming With Japanese-English Bilinguals

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The present research examined whether a lexical competition process operates when different-script bilinguals process L2 words. In masked priming lexical decision experiments (67 ms prime duration), word neighbor primes facilitated target identification for Japanese-English bilinguals (Experiment 1) although the same primes produced inhibitory effects for L1 English readers (Experiment 2). Subsequent experiments confirmed that the facilitory priming effects are reliable (Experiment 4), and are not due to bilinguals' inability to process masked L2 primes to the lexical level (Experiments 3 and 4) or bilinguals relying on sublexical activation from neighbor primes in responding to upper-case English targets (Experiment 5). Some evidence of lexical competition was observed, however, with clearly visible primes (Experiment 6, using a 175 ms prime duration). These results suggest that different-script bilinguals deal with orthographic similarity in L2 words differently from L1 readers. The authors discuss ways in which the L2 lexicon of different-script bilinguals may be different.

Public Significance Statement
The authors' examination of how bilinguals deal with visually similar words in their second language when that second language has a different writing system than their first language (Japanese-English bilinguals) showed that bilinguals process these words a bit differently than how native readers of a language do. The authors conclude, therefore, that the nature of second language reading, even for skilled bilinguals, is somewhat different than the nature of first language reading when the two languages involve different scripts.

Keywords: lexical competition, masked priming, different-script bilinguals, visual word recognition, L2 words

One of the key questions in bilingualism research is the nature of the interactions between the mental representations of the two languages. For example, in the domain of word recognition research, many studies have been devoted to examining how representations of L1 and L2 words are connected in the bilingual lexicon (e.g., De Groot & Nas, 1991; Finkbeiner, Forster, Nicol, & Nakamura, 2004; Gollan, Forster, & Frost, 1997; Jiang, 1999; Jiang & Forster, 2001; Kim & Davis, 2003; Kroll & Stewart, 1994; Potter, So, Von Eckardt, & Feldman, 1984; Voga & Grainger, 2007). On the other hand, less attention has been paid to understanding how bilinguals process L2 words and how those words, once learned, are represented in the bilingual lexicon. Although researchers generally seem to assume that L2 words are represented in much the same way as L1 words are, there is, at present, only a modicum of evidence that this assumption is true.

Understanding how L2 words are represented in the bilingual lexicon is important because doing so will not only help in building precise models of bilingual word recognition but also will contribute to the development of effective L2 teaching methods in educational settings. As such, the focus of the present research is understanding bilinguals' visual recognition process for L2 words. Specifically, we were interested in determining whether different-script bilinguals would show an inhibitory neighbor priming effect when processing words in their L2, an effect that is assumed to reflect the lexical competition processes involved in reading words in their L1. We will first review the literature on inhibitory orthographic neighbor priming effects observed in previous monolingual experiments and then discuss the lexical competition assumptions made by current models of visual word recognition in

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an effort to explain those effects. We then discuss the rationale and predictions for the present experiments.

Orthographic Neighbor Inhibition Effects for L1 Words

The masked inhibitory neighbor priming effect refers to the finding that identification of a target word (e.g., TIDE) is slower when that target is preceded by an orthographically similar word prime (e.g., side) relative to when the same target is preceded by an unrelated word prime of equal frequency (e.g., form). In this experimental paradigm, a prime is presented very briefly (e.g., 60 ms), is forward masked by a row of harsh marks (e.g., ######), and is then backward masked by the target itself. Participants are generally not aware of the presence of the prime. Masked priming effects are thought to tap relatively "pure" automatic lexical processes that are not contaminated by strategic and/or episodic factors (Forster & Davis, 1984). The experimental task that is most commonly used in masked neighbor priming studies is the lexical-decision task. Using this task, inhibitory neighbor priming effects have been observed in many studies using many different Indo-European languages (e.g., Andrews & Hersch, 2010; Brysbaert, Lange, & Van Wijnendaele, 2000; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; De Moor, Verguts, & Brysbaert, 2005; Drews & Zwitserlood, 1995; Duñabeitia, Laka, Perea, & Carreiras, 2009; Janack, Pastizzo, & Beth Feldman, 2004; Segui & Grainger, 1990), particularly when the prime is higher in frequency than the target, although there have been a few reports of a failure to find the effect (e.g., Burt & Duncum, 2017). In addition, recent studies have demonstrated that inhibitory neighbor priming effects can be observed with Japanese Katakana (Nakayama, Sears, & Lupker, 2011) as well as with Kanji stimuli (Nakayama, Sears, Hino, & Lupker, 2014), suggesting that these types of effects are quite general.[1]

The masked inhibitory orthographic neighbor priming effect is typically explained within the framework of localist, activation-based models (Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). These types of models assume that the word recognition system consists of three hierarchically organized, mutually interacting representational layers, which are specialized to detect feature-, letter-, and word-level representations of the word being read. In such models, the visual word recognition process starts with detecting a visual input. The visual input then activates feature-level detectors, which send excitatory signals to letter-level detectors representing letters that contain those visual features. The letter-level detectors in turn send excitatory signals to word detectors for the words containing the activated letters, causing representations of words containing those letters to become activated (especially words that have the shared letters in the same relative positions as those in the presented letter string).

These activation-based models further assume that intralayer connections are inhibitory at the word and letter levels. That is, once representations are partially activated at one of these levels, they start to suppress the activity levels of other representations at that same level. The inhibitory process among partially activated word representations is called *lexical competition* and it is particularly important in activation-based models, as successful word identification is possible only as a result of the competition between units being resolved.

Inhibitory neighbor priming effects are thought to reflect this lexical competition process embodied in these activation-based models. Specifically, presenting a neighbor prime causes its lexical representation to be activated as well as, to a lesser degree, the lexical representations of its neighbors. When the target is then presented, if it shares letters with the prime, those letters add activation to the prime's lexical level representation. As a result, the prime's representation becomes a strong competitor for the target, slowing target processing. As a consequence, lexical decisions are slower and more error prone when targets are primed by orthographic neighbors than by orthographically unrelated words.

In line with the argument that inhibitory priming effects from word neighbor primes reflect competition between the lexical representations of primes and targets, previous studies have shown that nonword neighbor primes typically facilitate target identification. That is, when nonword neighbor primes are used, priming effects are either facilitory (Davis & Lupker, 2006, for low *N* words) or null (Forster, 1987; Forster, Davis, Schoknecht, & Carter, 1987; Nakayama et al., 2011, for high *N* words), depending on the neighborhood size of the stimuli. The explanation for these effects is based on the idea that a nonword prime does not have a lexical (i.e., word-level) representation and, thus, it has no ability to activate a strong lexical competitor unlike when the prime is a word. Thus, the ability of a nonword prime to produce competition for the target is significantly reduced relative to that of a word prime, meaning that the activation that it supplies to the target's lexical representation leads to more rapid responding to the target.

Orthographic Neighbor Priming Effects With L2 Words

Although many studies indicate that lexical competition plays an important role in the L1 visual word recognition process, few studies have examined whether a similar process operates when bilinguals process L2 words. Bijeljac-Babic, Biardeau, and Grainger (1997) were among the first to examine this issue. In their first experiment, French-English bilinguals made lexical decisions to L2 English targets that were primed by higher-frequency English neighbor words or by unrelated English words (e.g., help-HELM vs. rich-HELM). The bilinguals responded to targets significantly slower when the targets were primed by neighbor primes relative to when they were primed by unrelated primes, demonstrating an inhibitory neighbor priming effect with L2 stimuli.

In the same set of studies, Bijeljac-Babic et al. (1997) also showed that lexical competition occurs across languages. That is, in their other experiments, the primes were words in one language

[1] Although many studies have demonstrated inhibitory priming effects from word neighbors, it is also clear that there are some constraints concerning when inhibitory priming effects will be observed. For instance, inhibitory priming effects typically do not occur for longer word targets (e.g., Forster, 1987; Forster & Veres, 1998), for low-*N* targets primed by lower-frequency neighbors (e.g., Nakayama, Sears, & Lupker, 2008), or when speed is stressed over accuracy (De Moor et al., 2005). Further, inhibitory effects seem to be somewhat reduced when the word/nonword discrimination is easy (e.g., Davis & Lupker, 2006). In the present experiments, we selected high-frequency prime and low-frequency target pairs all of which were 4–5 letters in length in order to maximize the chance of observing inhibitory effects (e.g., Segui & Grainger, 1990; Davis & Lupker, 2006).

and the targets were words in the other. When the prime was orthographically similar to the target, significant inhibition was observed in their lexical-decision task (e.g., joie-JOIN was slower than acte-JOIN; soil-SOIF was slower than gray-SOIF; also see Dijkstra, Hilberink-Schulpen, & Van Heuven, 2010, for a recent report of cross-language lexical competition with Dutch-English bilinguals). According to the bilingual version of the interactive-activation model (the BIA+ model, Dijkstra & van Heuven, 2002), lexical competition is expected to occur regardless of the words' language memberships when the two languages share a script because the orthographic lexicons of the two languages are integrated and the initial visual word recognition processes (e.g., letter activation) are language independent. Within this framework, lexical competition would, therefore, be expected to occur for L1 neighbors, L2 neighbors, and even neighbors across the two languages.

In contrast, there are theoretical positions that would suggest that inhibition effects would not be expected when L2 neighbor primes are used for L2 targets. The Episodic L2 hypothesis proposed by Forster and colleagues (Jiang & Forster, 2001; Witzel & Forster, 2012) is one. This hypothesis was developed to explain the seemingly puzzling finding that even though L2 translation primes often do not facilitate lexical decisions to L1 targets, the same L2 primes readily produce facilitation effects in episodic recognition tasks (i.e., when participants make speeded responses to the question "Did you see that L1 item in the study phase of the experiment?"). The core assumption of this hypothesis is that L1 word representations are stored in lexical memory, wheareas L2 word representations are stored in episodic memory. Further, episodic memory is assumed to be structured somewhat differently than lexical memory in that there is no assumption of competitive processes among episodic memory representations. Therefore, one would not expect to observe inhibition effects in any task that relies on episodic memory representations. Although this theory can provide a nice account of Forster and colleagues' findings, it would, of course, have trouble explaining Bijeljac-Babic et al.'s (1997) results.

A second position that could explain a null inhibition effect would be one based on Andrews and colleagues' (Andrews & Hersch, 2010; Andrews & Lo, 2012) lexical precision proposal. Their idea is that individuals differ in their ability to quickly isolate a word's lexical representation and, hence, in their ability to activate the prime sufficiently to make it a strong competitor. Readers who are weak in that ability, according to their performance in a set of language proficiency tasks, would not show inhibition effects. The fact that at least a certain percentage of university-level monolinguals may not be able to produce inhibition effects in their L1 implies that it would not be overly surprising if bilinguals were not able to produce inhibition effects in their L2. Presumably, however, same-script bilinguals would be more likely to show such effects than different-script bilinguals because the former can make use of their already established mental architecture as they build their L2 lexicon.

The Present Research

The central question in the present research was whether intra-language lexical competition operates when different-script bilinguals (i.e., Japanese-English bilinguals) process L2 (English) words. A major difference between different-script and same-script bilinguals is that different-script bilinguals need two different orthographic systems due to the fact that the two languages have different scripts. Thus, to become able to read L2 words, different-script bilinguals must first learn/encode a new orthography and then construct a lexicon that can deal with processing words in their L2. In contrast, same-script bilinguals can merely use their well-developed L1 orthographic system in the processing of L2 words. Therefore, one might expect that L2 word recognition processes of different-script bilinguals may be different from those of same-script bilinguals and, of course, also different from L1 word recognition processes of native speakers/readers of the language. The present examination of neighbor inhibition effects is one means of evaluating these issues.

Experiment 1 was a straightforward test of neighbor priming effects in which proficient Japanese-English bilinguals made lexical decisions to English targets that were preceded by English neighbor primes or unrelated primes. Prime lexicality was also manipulated. If the Japanese-English bilinguals show the same patterns of priming effects as observed in previous monolingual (e.g., Davis & Lupker, 2006) and same-script bilingual studies (Bijeljac-Babic et al., 1997), it would suggest that lexical competition operates in L2 word recognition processes for different-script bilinguals.

Experiment 1

Method

Participants. The participants were 52 proficient Japanese-English bilinguals from Waseda University (Tokyo, Japan). Their mean score on the TOEIC (Test of English for International Communication) was 849 (range = 730–990). All of the participants had normal or corrected-to-normal vision. On average, the age that they started studying English was 10.5 years (SD = 3.2).

Stimuli. Sixty-four English four- to five-letter words (M = 4.6 letters) were selected to serve as targets. The targets were medium-frequency words (M = 35.6 opm [occurrences per million]; Kučera & Francis, 1967) that had on average 5.5 orthographic neighbors. For each target (e.g., PITY), four types of primes were selected: (a) a higher-frequency word neighbor that differed from the target by a single letter (e.g., city): mean frequency 352 opm; (b) an unrelated control word that did not share any letters with the target in the same letter position (e.g., door): mean frequency 347 opm; (c) a nonword one-letter-different neighbor (e.g., lity); and (d) an unrelated control nonword that did not share any letters with the target (e.g., joor). For a given target, word neighbor and nonword neighbor primes always differed only in the identical letter position (e.g., city vs. lity, next vs. nect), as did the unrelated word and nonword primes (e.g., door vs. joor, area vs. arua). Thus, the only difference between the word primes and nonword primes was their lexicality. The four types of primes had the same letter lengths (M = 4.6) and equivalent numbers of neighbors (N = 4.4, 4.2, 4.4, and 4.1 for word neighbor, word unrelated, nonword neighbor, and nonword unrelated primes, respectively).

Sixty-four English four- to five-letter nonwords (M = 4.6 letters) were also selected. The targets on average had 5.1 orthographic neighbors. For each target (e.g., SOOM), four types of primes were selected paralleling those in the word target condition: (a) a high-frequency word neighbor (e.g., room): mean frequency 381 opm; (b) an unrelated control word (e.g., give): mean frequency 380 opm; (c) a nonword neighbor (e.g., goom); and (d) a nonword control prime (e.g., bive). The four types of primes had the same letter lengths ($M = 4.6$) and had equivalent numbers of neighbors ($N = 4.3$, 4.5, 4.3 and 4.2).[2]

For word targets and nonword targets, the stimuli were divided into four groups of prime-target pairs with the four groups having similar lexical characteristics (e.g., word lengths, frequency, *N* size, etc.). Four-counterbalanced lists were created so that within each list, each target was paired with one of the four prime types, but across lists, each target was paired with each of the four types of primes.

Apparatus and procedure. Each participant was tested individually. The trials were programmed and displayed using the DMDX software package (Forster & Forster, 2003). The prime duration was 67 ms, which was slightly longer than in previous masked priming studies investigating neighbor priming effects (e.g., 50–60 ms). This prime duration was selected with the expectation that it would be long enough to produce activation of the L2 primes, but not long enough for the primes to become visible. Each trial began with the presentation of a forward mask (######) for 500 ms, followed by the presentation of a prime in lower-case letters. Immediately following the prime, the target was presented in uppercase letters and remained on the screen 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, pressing the "word" or "nonword" button on a response box placed in front of them. Participants were given 16 practice trials prior to the experimental session.

Results

The data from three participants whose error rates were higher than 25% were removed and replaced by different participants while maintaining the counterbalancing of lists. Response latencies faster than 300 ms or slower than 1,800 ms were considered outliers and removed from the analyses (0.4% of the word target data and 0.6% of the nonword target data). Correct response latencies and error rates were analyzed separately with 2 (prime lexicality: words vs. nonwords) × 2 (prime type: neighbor vs. unrelated) within subject/item analyses of variance (ANOVAs). Table 1 shows mean reaction times (RTs) and error rates from Experiment 1.

Word targets. In the response latency data, the main effect of prime lexicality was not significant, $F_s < 1$; $F_i(1, 63) = 1.19$, $p > .10$. Overall response latency was not different for targets following word versus nonword primes (715 ms vs. 717 ms). The main effect of prime type was significant $F_s(1, 51) = 10.94$, $p < .01$, $MSE = 2565.2$, $\eta_p^2 = .18$; $F_i(1, 63) = 6.06$, $p < .05$, $MSE = 7644.1$, $\eta_p^2 = .09$. Unlike the effects typically observed in monolingual experiments, targets were responded to significantly *faster* when they were primed by neighbor primes than when those same targets were primed by unrelated primes (704 ms and 727 ms). There was no hint of interaction between prime lexicality and prime type, both Fs < 1, indicating that the facilitation effect was equally strong for targets primed by word neighbors (a 21-ms effect) and for targets primed by nonword neighbors (a 25-ms effect).

Table 1
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates for Word and Nonword Targets Primed by Word Neighbors, Unrelated Words Nonword Neighbors, and Unrelated Nonwords in Experiment 1

Targets	Word primes		Nonword primes	
	Reaction time	Errors	Reaction time	Errors
Word targets				
Neighbor	704	11.0%	704	12.2%
Unrelated	725	15.1%	729	13.5%
Priming	+21	+4.1%	+25	+1.3%
Nonword targets				
Neighbor	793	11.3%	781	11.8%
Unrelated	800	10.8%	803	10.2%
Priming	+7	−.5%	+22	−1.6%

The results in the error data were similar to those in the latency data. The main effect of prime lexicality was not significant, both Fs < 1, however there was a significant effect of prime type, $F_s(1, 51) = 6.10$, $p < .05$, $MSE = 62.0$, $\eta_p^2 = .11$; $F_i(1, 63) = 3.82$, $p = .05$, $MSE = 122.4$, $\eta_p^2 = .06$. The direction of the effect was again facilitory (11.6% vs. 14.3%). Unlike in the latency data, priming effects were numerically larger for word neighbor pairs (a 4.1% effect) than for nonword neighbor pairs (a 1.3% effect), however, the Prime Lexicality × Prime Type interaction was not significant, $F_s(1, 51) = 1.21$, $p > .10$; $F_i(1, 63) = 1.56$, $p > .10$.

Nonword targets. For response latency, the only significant effect was the main effect of prime type in the subject analysis, $F_s(1, 51) = 5.28$, $p < .05$, $MSE = 1911.2$, $\eta_p^2 = .09$; $F_i < 1$, which was facilitory. There were no other significant effects for nonword targets, all $F_s < 1.2$, $p > .20$.[3]

Power issues. In compliance with the new guidelines of the *Journal of Experimental Psychology: Human Perception and Performance*, we report here our analyses of the question of whether the present experiments had sufficient statistical power and precision. For each experiment, we first calculated the effect sizes of the variables of focal interest based on previous empirical studies. We used the equation presented in Lakens (2013), which uses *F* values and degrees of freedom from within-subject ANOVAs to obtain partial-eta squared values (η_p^2). Using G*power, we then evaluated whether the present experiments had sufficient sample sizes to

[2] According to the more recent index of written word frequency SUBTLEX-US (Brysbaert & New, 2009), the mean word frequency of the word targets was 41.2. The mean word frequencies of word neighbor primes and unrelated primes were 524.5 and 445.2, respectively. The mean word frequencies of word neighbor and unrelated primes preceding nonword targets were 464.2 and 346.5, respectively.

[3] For nonword targets, we report the results of the statistical analyses for interested readers but we will not attempt to provide an interpretation of those results because our focus is on the word target results (also see Burt, 2016). Indeed, neighbor priming effects for nonword targets are often unreliable in these types of experiments (e.g., Burt, 2009). Hence the practice of focusing exclusively on the word data is not at all uncommon in the previous literature with some studies failing to report the nonword target results entirely (e.g., Andrews & Lo, 2012; Massol, Molinaro, & Carreiras, 2015; Segui & Grainger, 1990).

achieve the desired power of .80 when α is set at .05 under the assumption that the effect sizes would be similar in our experiments.

For Experiment 1, the effect sizes for the word neighbor priming condition in L2 English (prime type) were determined based on the results of Bijeljac-Babic et al. (1997, Experiment 1) because those data were deemed the best estimate of neighbor priming effects in L2 available in the literature. Based on their analysis of the prime type effect obtained in that experiment, the effect sizes (η_p^2) were estimated to be 0.37 and 0.39 for subjects and items, respectively. Using those estimates, the minimum sample sizes necessary to achieve the desired power in our Experiment 1 were calculated to be 16 subjects and 15 items. As such, our sample sizes of 52 subjects and 64 items were large enough to allow us sufficient power.

Discussion

The question addressed in Experiment 1 was whether Japanese-English bilinguals would produce an inhibitory priming effect from word neighbor primes when responding to English (L2) targets. Such an effect, if observed, would indicate that lexical competition operates in L2 visual word recognition for different-script bilinguals. The results were very clear. There was no evidence for lexical competition for our Japanese-English bilinguals and, in fact, word neighbor primes facilitated L2 word recognition to the same degree as nonword neighbor primes. This result was the opposite of what has been observed in previous experiments testing L1 readers (e.g., Andrews & Hersch, 2010; Davis & Lupker, 2006; De Moor et al., 2005; Duñabeitia et al., 2009; Nakayama et al., 2008; Segui & Grainger, 1990) and in previous experiments testing same-script bilinguals (Bijeljac-Babic et al., 1997). Note also that significant inhibition effects from word neighbor primes (and facilitation effects from nonword neighbor primes, i.e., a "prime lexicality effect") have been observed for Japanese readers performing the task in their L1 (Nakayama et al., 2011, 2014). Therefore, the lack of a prime lexicality effect in Experiment 1 does not appear to be due to the fact that our participants' L1 was Japanese. Rather, these results appear to be due to the fact that L2 stimulus processing is somewhat different than L1 stimulus processing.

The facilitation effect from nonword neighbor primes was not particularly surprising, given that nonword neighbor primes are known to produce facilitation effects especially when they have few neighbors (i.e., low *N*s; e.g., Andrews & Hersch, 2010; Davis & Lupker, 2006). The nonword primes used in Experiment 1 had a moderate neighborhood size ($M = 5.5$), but it was likely that those nonwords were functionally low *N* words for the bilinguals because their English vocabulary sizes would be smaller than those of L1 English readers. The important question arising from Experiment 1, therefore, is why did the word neighbor primes facilitate target identification to the same extent that nonword neighbor primes did?

One possibility is that the observed effects for these individuals were sublexical, rather than lexical, in nature. That is, perhaps the prime duration was sufficiently short that participants were only able to activate sublexical representations. Hence, the priming observed in Experiment 1 would have been the result of the activation of the letters that were shared between the prime and target. If so, not only would the priming be expected to be facilitory but also, there would have been no distinction between word and nonword primes. This possibility seems somewhat unlikely, however, because many previous studies have shown significant repetition priming effects for L2 words with a 50-ms prime duration (e.g., Finkbeiner et al., 2004; Jiang, 1999; Nakayama, Sears, Hino, & Lupker, 2013), indicating that a 67-ms prime duration should have been long enough to activate the lexical representations of L2 primes. Nonetheless, based on the facts that (a) there was some suggestion of facilitation for nonword targets (at least following nonword primes) and (b) null L2 repetition priming effects for words targets have previously been observed for different-script bilinguals (e.g., Xia & Andrews, 2015, Experiment 1B), this possibility was deemed to be worth a closer examination.

Before doing so, however, in Experiment 2, we conducted a control experiment. The purpose of this experiment was to determine whether the pattern observed in Experiment 1 could have been a result of some unusual characteristics of the stimuli used. In Experiment 2, L1 English readers made lexical decisions to the same set of stimuli used in Experiment 1. Based on the previous masked priming studies in the literature, we expected to observe significant inhibitory priming from word neighbor primes. We also expected the priming effect from nonwords to be either null or facilitory.

Experiment 2

Method

Participants. Forty students from the University of Arizona participated in this experiment. All participants were L1 speakers/readers of English and had normal or corrected-to-normal vision.

Stimuli. The same set stimuli used in Experiment 1 was used.

Apparatus and procedure. These were identical to those in Experiment 1.

Results

Response latencies faster than 300 ms or slower than 1,500 ms were considered as outliers and removed from the analyses (0.3% of the word data and 0.4% of the nonword data). Note that the upper cutoff value was shorter than in Experiment 1 because participants were responding to L1 targets in Experiment 2. The data were analyzed in the same way as in Experiment 1. Table 2 shows mean RTs and error rates from Experiment 2.

Word targets. For response latency, the main effect of prime lexicality was marginally significant in the subject analysis and was significant in the item analysis, $F_s(1, 39) = 3.23$, $p = .08$, $MSE = 787.2$, $\eta_p^2 = .08$; $F_i(1, 63) = 4.50$, $p < .05$, $MSE = 1270.2$, $\eta_p^2 = .07$. Overall responses tended to be slower when targets were primed by words than by nonwords (571 ms vs. 563 ms). The main effect of prime type was also significant, $F_s(1, 39) = 8.28$, $p < .01$, $MSE = 1225.0$, $\eta_p^2 = .18$; $F_i(1, 63) = 8.36$, $p < .01$, $MSE = 2239.6$, $\eta_p^2 = .12$. Strikingly different from the bilingual data, but consistent with previous studies, was that the direction of the priming effect was inhibitory. When targets were primed by word neighbors, responses were significantly slower than when the same targets were primed by unrelated words (575 ms vs. 559 ms).

Table 2
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates for Word and Nonword Targets Primed by Word Neighbors, Unrelated Words, Nonword Neighbors, and Unrelated Nonwords in Experiment 2 (L1 English Readers)

Targets	Word primes		Nonword primes	
	Reaction time	Errors	Reaction time	Errors
Word targets				
Neighbor	582	10.0%	568	6.6%
Unrelated	560	6.3%	558	5.5%
Priming	−22	−3.7%	−10	−1.1%
Nonword targets				
Neighbor	664	12.0%	627	9.4%
Unrelated	630	10.0%	640	10.6%
Priming	−34	−2.0%	+13	+1.2%

Where the present data did diverge from Davis and Lupker's (2006) results is that the Prime Lexicality × Prime Type interaction was not significant in the subject analysis, $F_s(1, 39) = 1.39$, $p > .20$; although it was significant in the item analysis, $F_i(1, 63) = 3.94$, $p = .05$, $MSE = 1053.8$, $\eta_p^2 = .06$. Follow-up analyses revealed that, most importantly for present purposes, the word neighbor primes produced significant inhibitory priming (a −22 ms effect), $t_s(39) = 3.83$, $p < .01$, $SEM = 5.6$; $t_i(63) = 3.10$, $p < .01$, $SEM = 8.1$. The lack of a significant interaction was due to the fact that the nonword neighbors also produced a small, but nonsignificant, inhibition effect (−10 ms), $t_s(39) = 1.19$, $p > .10$; $t_i(63) = 1.49$, $p > .10$.

For errors, the main effect of prime lexicality was significant in the subject analysis, and was marginally significant in the item analysis, $F_s(1, 39) = 4.02$, $p = .05$, $MSE = 44.3$, $\eta_p^2 = .09$; $F_i(1, 63) = 3.33$, $p = .07$, $MSE = 85.6$, $\eta_p^2 = .05$; error rates were higher for targets primed by words than by nonwords (8.2% vs. 6.1%). The main effect of prime type was also significant, $F_s(1, 39) = 3.92$, $p = .05$, $MSE = 59.8$, $\eta_p^2 = .09$; $F_i(1, 63) = 8.45$, $p < .01$, $MSE = 44.4$, $\eta_p^2 = .12$. Again, the priming effect was inhibitory; error rates were significantly higher when targets were primed by word orthographic neighbors than by unrelated words (8.3% vs. 5.9%). Consistent with the latency data, the inhibition effect was numerically larger for word neighbor prime-target pairs (3.7%) than for nonword neighbor prime-target pairs (1.1%), however, this difference was not statistically significant as indicated by null interaction between prime lexicality and prime type, $F_s(1, 39) = 1.91$, $p > .10$; $F_i(1, 63) = 1.63$, $p > .10$.

Nonword targets. For response latency, the main effect of prime lexicality was significant, $F_s(1, 39) = 5.43$, $p < .05$, $MSE = 1260.3$, $\eta_p^2 = .12$; $F_i(1, 63) = 4.91$, $p < .05$, $MSE = 2282.3$, $\eta_p^2 = .07$, with slower responses for targets primed by words than by nonwords (647 ms vs. 634 ms). The main effect of prime type was significant in the subject analysis and was marginally significant in the item analysis, $F_s(1, 39) = 5.17$, $p < .05$, $MSE = 908.2$, $\eta_p^2 = .12$; $F_i(1, 63) = 3.12$, $p = .08$, $MSE = 2006.3$, $\eta_p^2 = .05$. There was a significant interaction between prime lexicality and prime type, $F_s(1, 39) = 19.33$, $p < .001$, $MSE = 1163.1$, $\eta_p^2 = .33$; $F_i(1, 63) = 13.11$, $p < .001$, $MSE = 2695.2$, $\eta_p^2 = .17$. Follow-up analyses of the interaction showed that significant inhibitory priming was observed for targets primed by words (a 34-ms effect), $t_s(39) = 4.83$, $p < .001$, $SEM = 7.1$; $t_i(63) = 4.07$, $p < .001$, $SEM = 8.2$. In contrast, the direction of the effect was facilitory for targets primed by nonwords (a 13-ms effect), a difference that was not statistically significant, $t_s(39) = 1.78$, $p = .08$, $SEM = 7.2$; $t_i(63) = 1.53$, $p > .10$. In the error data, there were no significant effects, all Fs < 2.3, ps $> .10$.

Power issues. For Experiment 2, the effect sizes for the word neighbor priming condition in L1 English (prime type) were determined based on the results of Nakayama et al. (2008, Experiments 1 and 2; higher-frequency and lower-frequency prime-target neighbor pair conditions). The estimated effect sizes (η_p^2) of the priming effects ranged from 0.30 to 0.51 for subjects and 0.20 to 0.27 for items. Assuming that the effect sizes are similar across studies, the sample sizes necessary to achieve the desired power were calculated to be 10–20 subjects and 24–34 items. As such, our sample sizes of 40 subjects and 64 items were large enough to allow us sufficient power.

Discussion

In Experiment 2, consistent with previous studies with L1 English readers (e.g., Davis & Lupker, 2006; Nakayama et al., 2008), word neighbor primes significantly inhibited word target identification relative to unrelated primes. Nonword neighbor primes, in contrast, produced a null effect relative to unrelated primes. It should be noted, of course, that unlike previous monolingual studies in English (Davis & Lupker, 2006), we did not observe a statistically clear Prime Type × Prime Lexicality interaction in the subject analysis (the interaction was significant only in the item analysis) mainly because the nonword primes did not produce a facilitation effect. Although it isn't clear why the nonword primes were ineffective, a likely possibility is that our stimuli had more neighbors than Davis and Lupker's stimuli ($N = 5.5$ vs. 2.2). As Nakayama et al. (2008) have demonstrated, nonword primes with larger N sizes are less effective at producing facilitation effects and, if N is large enough, can even produce inhibition effects. In any case, the most relevant finding of Experiment 2 was that L1 English readers showed a significant inhibitory priming effect from word neighbor primes with the present set of primes and targets. Therefore, the observation of a significant facilitory effect in Experiment 1 is unlikely to have been due to some idiosyncratic characteristics of the stimuli used. Rather, it appears to be because the participants were different-script bilinguals responding to L2 words.

Experiment 3

The results of Experiment 1 (with Japanese-English bilinguals) showed that word and nonword neighbor primes equally strongly facilitated target identification. As noted earlier, one possible reason is that a 67-ms prime duration may have been too short for our bilinguals to have activated their lexical representations of L2 primes. If these primes' lexical representations were not activated, then there would have been no lexical competition. However, there would have been sublexical activation involving shared letter units between neighbor pairs which could have produce the equivalent priming effects from word and nonword neighbor primes.

In Experiment 3, we examined this possibility by looking at (a) L2 repetition priming effects, and (b) L2-L1 noncognate translation priming effects for Japanese-English bilinguals at the same fluency level as the participants in our Experiment 1. In the first priming condition, we examined whether bilinguals would show L2 repetition priming effects (e.g., book-BOOK). Strong repetition priming effects in L2 would provide some evidence that a 67-ms prime duration is sufficiently long for L2 primes to activate lexical level information.

The second priming condition (the L2-L1 translation priming condition) was a stronger examination of L2 prime processing. In this condition, a Japanese target (e.g., 屋根) was primed by its noncognate English translation equivalent (e.g., roof) or an unrelated English word (e.g., baby). Because noncognate translation equivalents do not share orthography or phonology, no sublexical level facilitation would be expected in this situation. If significant translation priming is observed from L2 primes, it must mean that these English primes were processed to the lexical/conceptual level. It should be noted, however, that the L2-L1 noncognate translation priming effect is known to be difficult to observe, especially with different-script bilinguals (e.g., Jiang, 1999; Jiang & Forster, 2001). Nevertheless, recent studies have shown that obtaining significant L2-L1 noncognate translation priming effects is possible for bilinguals who are as proficient as the ones in Experiment 3 (Nakayama, Ida, & Lupker, 2016, 2017) and hence this priming condition was included in our examination of L2 prime processing in Experiment 3.

Method

Participants. Forty-four Japanese-English bilinguals from Waseda University (Tokyo, Japan) participated in this experiment. None had participated in Experiment 1. The participants were recruited from the same, relatively large participant pool of bilinguals used for Experiment 1. Their L2 proficiency was similar to the bilinguals who participated in Experiment 1; their mean TOEIC score was 858 (range = 730–990). All of the participants had normal or corrected-to-normal vision.

Stimuli. The stimuli were the same materials used previously in Nakayama et al. (2013, Experiment 2). In the English identity priming condition, the targets were 60 English words and nonwords (mean word lengths were both 4.7). For word targets, half of the targets were high-frequency words (M = 63 opm) and the other half were low-frequency words (M = 12 opm).[4] Each target was primed by either the target itself (e.g., roof–ROOF) or by an unrelated prime (e.g., wage–ROOF). Like the word targets, the nonword targets were primed by either the target itself (repetition primes) or by an unrelated prime. For both word and nonword targets, two counterbalanced lists were created, so that if a target was paired with a repetition prime in the first list it was paired with an unrelated prime in the second list, and vice versa.

In the L2-L1 noncognate translation priming condition, the stimuli were taken from previous masked priming experiments with bilinguals (Nakayama et al., 2013, Experiment 2 and Nakayama et al., 2016, Experiment 3). The targets were 60 Japanese two-character low-frequency Kanji words (M = 8 opm, according to Amano & Kondo, 2003). Each target (e.g., 天使, /te.N.si/) was primed either by its English translation equivalent (e.g., angel) or an unrelated English word (e.g., waist). The mean word frequencies of the English translation primes and unrelated primes were 51 and 50 opm, respectively. Japanese nonword targets were created by combining two Kanji characters in such a way that the particular combination does not constitute a word in the Japanese vocabulary. Each nonword target (e.g., 瞬本) was preceded by an English word (e.g., dance). The mean word frequency of English primes preceding Japanese nonword targets was matched to that of the primes in the word target condition (M = 50). Prime type was not manipulated for nonword targets, and thus there was only one presentation list for nonword targets.

Apparatus and procedure. These were essentially identical to those in the previous experiments, except that bilinguals were presented with the L2-L1 translation condition and the L2 repetition condition in a counterbalanced fashion (i.e., half of the bilinguals was assigned to L2-L1 task first and then the L2 repetition task, and the other half received the two tasks in the reverse order).

Results

The data from one participant were removed because that person's RTs were consistently slower than 1 second in the L2 repetition priming condition. That participant's data were replaced by those from an additional participant while maintaining the counterbalancing of the presentation lists. For the L2 repetition condition (L2 targets), response latencies faster than 300 ms or slower than 1,800 ms were considered outliers and removed from the analyses (0.1% of the word data and 0.2% of the nonword data). Correct response latencies and error rates were analyzed by 2 (target frequency: low vs. high) × 2 (prime type: repetition vs. unrelated) ANOVAs. Prime type was a within-subject/item factor, and target frequency was a within-subject factor and a between-item factor. Nonword targets were analyzed using a single factor (prime type) within-subject/item ANOVAs. For the L2-L1 noncognate priming condition (L1 targets), response latencies faster 300 ms or slower than 1,500 ms were considered outliers and removed from the analyses (0.1% of the word data). For the translation priming condition, only word targets were analyzed using a single-factor within-subject/item ANOVAs. Table 3 shows mean RTs and error rates from Experiment 3.

L2 repetition priming effects. Response latency analyses showed that for word targets there was a main effect of target frequency, $F_s(1, 43) = 46.46$, $p < .001$, $MSE = 1755.4$, $\eta_p^2 = .52$; $F_i(1, 58) = 12.36$, $p < .01$, $MSE = 6218.5$, $\eta_p^2 = .18$. As expected, low frequency targets were responded to much slower than high frequency targets (648 ms vs. 605 ms). There also was a repetition priming effect for the L2 words, $F_s(1, 43) = 109.17$, $p < .001$, $MSE = 2529.6$, $\eta_p^2 = .72$; $F_i(1, 58) = 192.75$, $p < .001$, $MSE = 1340.4$, $\eta_p^2 = .77$. There was no interaction between target frequency and prime type, both Fs < 1. The sizes of L2 repetition priming effect were statistically equivalent for high-frequency targets (an 83 ms effect) and low-frequency targets (a 76 ms effect). This result is the typical result found in previous repetition

[4] According to the SUBTLEX-US (Brysbaert & New, 2009), for the stimuli used to test L2-L2 repetition priming, the mean word frequencies of the high-frequency targets (and the repetition primes) and the low-frequency targets (and the repetition primes) were 106.3 and 23.7, respectively. For the word stimuli used to investigate L2-L1 translation priming, the mean word frequencies of translation primes and unrelated primes preceding Japanese word targets were 67.4 and 57.2, respectively. The mean word frequency of English primes preceding Japanese nonword targets was 49.5.

Table 3
Mean Reaction Times (in Milliseconds) and Error Rates for English Word and Nonword Targets Primed by Repetition Primes and Unrelated Words, and for Japanese Word Targets Primed by English Noncognate Translation Equivalents and Unrelated Words in Experiment 3

L2-L2 repetition priming condition				
	Word targets			
	High-frequency targets		Low-frequency targets	
	Reaction time	Error	Reaction time	Error
Repetition	564	3.2	610	11.4
Unrelated	646	10.0	686	20.6
PE	+83	+6.8	+76	+9.2
	Nonword targets			
	Reaction time	Error		
Repetition	693	11.4		
Unrelated	698	8.9		
PE	+5	−2.5		

L2-L1 noncognate translation priming condition		
	Reaction time	Error
Translation	539	4.2
Unrelated	563	6.4
PE	+24	+2.2

priming experiments when using L1 English targets (e.g., Forster & Davis, 1984; Forster, Mohan, Hector, Kinoshita, & Lupker, 2003).

The error analyses mirrored the response latency analyses. The main effect of target frequency was significant, $F_s(1, 43) = 49.99$, $p < .001$, $MSE = 77.7$, $\eta_p^2 = .54$; $F_i(1, 58) = 8.90$, $p < .01$, $MSE = 316.8$, $\eta_p^2 = .13$, with low-frequency targets producing more errors than high-frequency targets (15.3% vs. 7.3%). The main effect of prime type was also significant, documenting an L2 repetition effect, $F_s(1, 43) = 30.95$, $p < .001$, $MSE = 91.65$, $\eta_p^2 = .42$; $F_i(1, 58) = 40.22$, $p < .001$, $MSE = 48.1$, $\eta_p^2 = .41$. The two-way interaction between target frequency and prime type was not significant, $F_s(1, 43) = 1.01$, $p > .10$; F_i $(1, 58) = 1.43$, $p > .10$. Priming effects for low- and high-frequency targets were statistically equivalent (9.2% vs. 6.8%).

For nonword targets, no repetition priming effect was observed in response latency (693 ms vs. 698 ms), both Fs < 1. In the analysis of error rates, there was a statistically significant repetition priming effect (−2.5%), $F_s(1, 43) = 7.18$, $p < .05$, $MSE = 22.8$, $\eta_p^2 = .14$; $F_i(1, 59) = 6.90$, $p < .05$, $MSE = 28.9$, $\eta_p^2 = .14$. This repetition priming effect was very small and also was in the opposite direction of the small effect in the latency data (see Perea, Marcet, Vergara-Martinez, and Gomez (2016) for an explanation of why one might expect a small inhibitory effect of nonword repetition primes).

L2-L1 noncognate translation priming effect. There was a significant L2-L1 noncognate priming effect in the response latency data as indicated by the significant main effect of prime type, $F_s(1, 43) = 12.58$, $p < .001$, $MSE = 988.8$, $\eta_p^2 = .23$; $F_i(1, 59) = 31.11$, $p < .01$, $MSE = 592.0$, $\eta_p^2 = .35$. A significant L2-L1 priming effect was also observed for errors, $F_s(1, 43) = 7.36$, $p = .01$, $MSE = 13.5$, $\eta_p^2 = .15$; $F_i(1, 59) = 7.21$, $p < .01$, $MSE = 18.7$, $\eta_p^2 = .11$. Japanese targets primed by English noncognate translation primes were responded to significantly faster and more accurately (539 ms and 4.2%) than the same targets primed by unrelated English primes (563 ms and 6.4%).

Power issues. For Experiment 3, the effect sizes for the L2-L2 repetition priming condition (prime type) were determined based on the results of Nakayama et al. (2013, Experiment 2, more proficient bilinguals). In that experiment, the identical set of stimuli was used to test similarly proficient Japanese-English bilinguals. The effect sizes [η_p^2] of the priming effects were .74 and .49 for subjects and items, respectively. Assuming that the effect sizes are similar across the two experiments, the necessary sample sizes were calculated to be five subjects and 11 items. As such, our sample sizes of 44 subjects and 60 items were large enough to allow us sufficient power.

The effect sizes for the L2-L1 translation priming condition (prime type) were determined based on the results of Nakayama et al. (2016, Experiment 2). In that experiment, the identical set of stimuli was used with Japanese-English bilinguals of similar proficiency. The effect sizes (η_p^2) of the priming effects were .26 and .25 for subjects and items, respectively. Assuming that the effect sizes are similar across the two experiments, the necessary sample sizes were calculated to be 25 subjects and 26 items. As such, our sample sizes of 44 subjects and 60 items were large enough to allow us sufficient power.

Discussion

In Experiment 3, Japanese-English bilinguals produced clear repetition priming effects for English words, suggesting lexical involvement in L2 prime processing. The sizes of priming effects were not modulated by target frequency, paralleling the more commonly observed pattern in English (e.g., Forster & Davis, 1984). Further, the size of the L2 repetition priming effect was more than three times as large as the L1 neighbor priming effects observed in Experiment 1, suggesting that L2 identity primes and L2 neighbor primes had somewhat different impacts for different-script bilinguals even though differences between the two types of primes are very small in terms of their orthographic relationships with their targets (i.e., repetition and neighbor primes differ just by one letter).

Even stronger evidence for lexical (and conceptual) involvement in L2 prime processing was observed in the L2-L1 translation priming data. These results not only showed that L2-L1 noncognate translation priming is a reliable phenomenon for highly proficient bilinguals, but also strongly suggested that for our highly proficient Japanese-English bilinguals, a 67 ms prime duration was sufficiently long for L2 (prime) words to be processed to the lexical/conceptual level.

The results of Experiment 3, therefore, indicated that L2 neighbor primes presented for 67 ms are processed well beyond the sublexical level by highly proficient Japanese-English bilinguals. Of course, one could argue this conclusion is weakened because different groups of bilinguals participated in Experiments 1 and 3. However, as the two groups of bilinguals had matched L2 proficiencies (their mean TOEIC scores were 849 and 858, respectively) it is reasonable to assume that they had similar L2 prime processing skills.

Nevertheless, to make our claim stronger, we reexamined this issue in an additional experiment. In Experiment 4, the same group of bilinguals performed both L2-L2 neighbor priming and L2-L1 translation priming tasks. We selected a new set of stimuli in such a way that the same L2 prime could serve as (a) an orthographic neighbor prime for an English target (e.g., time–TIDE) in the L2-L2 neighbor priming task and as (b) an English translation prime for a Japanese target (e.g., *time*–時間) in the L2-L1 translation priming task. Successful replications of the results of the preceding experiments (Experiments 1 and 3) would provide very strong evidence that, for different-script bilinguals, word orthographic neighbor primes facilitate rather than inhibit L2 target identification despite the fact that those primes are processed to the lexical/conceptual level.

Experiment 4

Method

Participants. Thirty-two Japanese-English bilinguals from Waseda University (Tokyo, Japan) participated in this experiment. Their mean TOEIC score was 882 (range = 800–990). All of the participants had normal or corrected-to-normal vision.

Stimuli. To create the orthographic neighbor priming pairs, 92 English four- to five-letter words (M = 4.4 letters) were selected to serve as targets. In this experiment, we used SUBTLEX-US frequency (Brysbaert & New, 2009) as an index of word frequency rather than Kučera-Francis (1967) frequency. The mean word frequency of the targets was 21 opm. The targets had, on average, 8.7 orthographic neighbors. For each target (e.g., FLOOD), two types of primes were selected: (a) a higher-frequency word neighbor that differed from the target by a single letter (e.g., blood): mean frequency = 262 opm and mean N size = 8.0; (b) an unrelated control word that did not share any letters with the target in the same letter position (e.g., speak): mean frequency = 263 opm and mean N size = 7.7. For the L2-L1 translation priming pairs, 92 Japanese two-character Kanji words (e.g., 血液) were selected to serve as targets. The mean word frequency of the word targets was 42 opm and the number of strokes was 18.5. English primes used in the L2-L1 translation condition were the same as those used in the orthographic neighbor priming condition. That is, English primes that were orthographic neighbors of the English targets (blood–FLOOD) were also translation equivalents of the Japanese targets (e.g., blood–血液). Unrelated primes were conceptually, phonologically and orthographically unrelated to their targets (e.g., speak–血液).

The counterbalancing of lists was done in a way to avoid repeating a prime to any participant. To do so, the 92 pairs of English primes (related and unrelated) were first divided into two sets with similar lexical characteristics (e.g., A and B). Each set of primes either primed English targets in the neighbor priming task or Japanese targets in the translation priming task. That is, when the primes in set A preceded English targets (46 items), then the primes in Set B preceded Japanese targets (46 items) and vice versa. Within each set of prime pairs, half of the primes were related to their targets and other half were unrelated. Thus, for each participant, each critical prime preceded either the English or the Japanese targets but never both.

For the neighbor priming task and the translation priming task, respectively, 46 English nonwords and 46 Japanese nonwords were also selected for "no" responses. In the neighbor priming condition, English nonword targets were on average 4.4-letters long (range: 4–5) and had a mean N size of 8.7. Half of the nonwords were primed by English word neighbors and the other half were primed by unrelated English words. The primes preceding nonword targets were matched in word frequency (M = 252), word length (M = 4.4), and N size (N = 8.0) with the primes preceding the English word targets. For nonword targets, prime type was not counterbalanced across participants and there was only one presentation list. In the translation priming task, Japanese nonwords were created by combining two Kanji characters to produce a character string that does not exist in the Japanese vocabulary. The mean number of strokes in the nonword targets (M = 18.6) was matched to that in the Japanese word targets. All Japanese nonwords were primed by English primes that were matched in word frequency (M = 261), word length (M = 4.4) and N size (N = 7.8) with the primes preceding Japanese word targets. There also was only one presentation list for the translation priming task.

Apparatus and procedure. The priming procedure was identical to that in the previous experiments. Priming tasks were blocked. Bilinguals were presented with the L2-L1 translation and L2 neighbor priming tasks in a counterbalanced manner, such that half of the bilinguals received the L2-L1 task first and the other half received the L2 neighbor priming task first.

Results

The data from one participant were removed due to a high error rate in the neighbor priming condition (>25%) and that participant was replaced by an additional participant while maintaining the counterbalancing of the presentation lists. For the neighbor priming task (L2 targets), response latencies faster than 300 ms or slower than 1,800 ms were considered outliers and removed from the analyses (0.3% of the word data and 0.2% of the nonword data). For the translation priming task (L1 targets), response latencies faster than 300 ms or slower than 1,500 ms were removed from the analyses (0.5% of the word data). Because we were not interested in comparing the sizes of neighbor priming effects and translation priming effects, we analyzed the tasks in separate ANOVAs. For the two priming effects, correct response latencies and error rates were analyzed using 2 (target set: Set A or B) × 2 (prime type: related vs. unrelated) ANOVAs. Target set was between-subjects/item factors and prime type was a within-subject/item factor. Table 4 shows mean RTs and error rates from Experiment 4.

Word neighbor priming effects. The main effect of prime type was significant, $F_s(1, 30) = 10.35$, $p < .01$, $MSE = 1112.5$, $\eta_p^2 = .26$; $F_i(1, 90) = 4.93$ $p < .05$, $MSE = 7730.1$, $\eta_p^2 = .05$. Consistent with the result of Experiment 1, targets primed by word orthographic neighbors were again responded to significantly faster than the same targets primed by unrelated words (665 ms vs. 692 ms). There was no effect of target set, both Fs < 1. The interaction between prime type and target set was also not significant, $F_s(1, 30) = 1.45$, $p > .10$; $F_i(1, 90) = 2.92$, $p = .09$. No

Table 4
Mean Reaction Times (in Milliseconds) and Error Rates for English Word and Nonword Targets Primed by Word Neighbor Primes and Unrelated Words, and for Japanese Word Targets Primed by Translation Primes Equivalents and Unrelated Words in Experiment 4

Condition	Reaction time	Error
L2-L2 neighbor priming condition		
Repetition	665	14.1
Unrelated	692	14.4
PE	+27	−.3
L2-L1 noncognate translation priming condition		
Translation	501	4.4
Unrelated	518	8.1
PE	+17	+3.7

Note. Mean response latencies and error rates for nonword targets were 709 ms and 8.6% in the L2-L2 neighbor priming task, and were 568 ms and 3.7% in the L2-L1 translation priming task.

significant effects were observed in the error data, all Fs < 2.2, $p > .10$.

Translation priming effects. The main effect of prime type was significant, $F_s(1, 30) = 13.62$, $p < .001$, $MSE = 389.5$, $\eta_p^2 = .31$; $F_i(1, 90) = 14.42$, $p < .001$, $MSE = 1877.2$, $\eta_p^2 = .14$. Targets primed by translation equivalents, that is, the same English primes that also served as orthographic neighbor primes, were responded to significantly faster than the same targets primed by the same unrelated primes (501 ms vs. 518 ms). There was no main effect of target set in the subject analysis, $F_s < 1$, but the effect was significant in the item analysis, $F_i(1, 90) = 4.56$, $p < .05$, $MSE = 5701.0$, $\eta_p^2 = .05$. This result is due to the fact that overall responses were significantly faster for one set of (Japanese) target items than the other. Nonetheless, there was no interaction between prime type and target set, $F_s(1, 30) = 1.47$, $p > .10$; $F_i(1, 90) = 1.13$, $p > .10$, indicating that the priming effects were equivalent across the two target sets. For errors, there was a significant main effect of prime type, $F_s(1, 30) = 8.92$, $p < .01$, $MSE = 26.0$, $\eta_p^2 = .23$; $F_i(1, 90) = 9.46$, $p < .05$, $MSE = 70.4$, $\eta_p^2 = .10$, due to there being a 3.7% facilitory priming effect. There were no other significant effects for errors, all Fs < 1.

Power issues. For Experiment 4, the effect sizes for the L2-L2 neighbor priming task (prime type) were determined based the results of the present Experiment 1. The effect sizes (η_p^2) of (facilitory) L2-L2 neighbor priming were .18 and .09, for subjects and items, respectively. Assuming similar effect sizes across experiments, the required sample sizes were calculated to be 38 subjects and 82 items. As such, our sample sizes of 32 subjects (but not 92 items) slightly fell short of achieving the desired power of .80. Nonetheless, the critical results were successfully replicated.

The effect sizes for the L2-L1 translation priming task (prime type) were determined based on the results of the previous studies of Nakayama et al. (2016, 2017) and the present Experiment 3, in which similarly proficient Japanese-English bilinguals were tested. For the subject analyses, the effect sizes [η_p^2] ranged from .18 and .31, with an average of .26. For the item analyses, the effect sizes ranged from .10 and .45, with an average of .18. Assuming similar effect sizes across experiments, the required sample sizes based on the average effect sizes were calculated to be 25 subjects and 38 items. As such, our sample sizes of 32 subjects and 92 items were large enough to allow us sufficient power.

Discussion

The results were clear-cut. Word neighbor primes again facilitated the recognition of L2 targets, and such was the case even though L2 primes were processed to the conceptual level as evidenced by the significant L2-L1 noncognate translation priming effect. Thus, word neighbor priming effects for our Japanese-English bilinguals are highly unlikely to be a reflection of sublexical level facilitation due to the fact that the primes could only be processed to the sublexical level.

Experiment 5

The results of Experiments 3 and 4 clearly showed that proficient bilinguals are capable of processing 67-ms masked English primes efficiently. A more likely explanation of the lack of any evidence of inhibition in Experiments 1 and 4, therefore, is that there are differences in bilinguals' and native English readers' representations for English words. The next experiments were designed to provide a further examination of that idea.

One observation of those doing bilingual research involving different-script bilinguals whose L2 is English is that those bilinguals often mention that it is not very easy for them to process targets presented in upper-case form (e.g., Jiang, 1999, Experiment 3). Our Japanese-English bilinguals also often mentioned that upper-case English words are difficult to read because those individuals are much more familiar with English words written in lower-case letters. This observation may have important implications for word neighbor priming experiments. That is, because processing upper-case English words is difficult, the bilinguals may be processing upper-case targets in an unusual way, relying heavily on letter level activation. If so, such a strategy may have heightened the impact of letter level activation from the prime on target processing.

More specifically, the idea is that bilinguals are capable of processing L2 lower-case primes beyond the sublexical level (as demonstrated in Experiments 3 and 4), but when faced with a lexical-decision task involving upper-case targets, they may focus more on the available letter-level activation (to compensate for their weak processing abilities of upper-case English targets). To examine this idea, in Experiment 5, both primes and targets were presented in lower-case. If bilinguals' focus on letter-level representations was the cause of the facilitory neighbor priming effects, a similar pattern of results should not be observed in Experiment 5.

It is, of course, not impossible that presenting prime-target pairs in the same letter case could increase facilitory priming effects due to increased featural overlap between primes and targets if those primes and targets were presented in the same font size and type. Therefore, we used different font sizes and types in Experiment 5. Any remaining concerns about the fact that the primes and targets were both presented in lower case would seem to be addressed by the fact that we have previously observed significant inhibition from Japanese word neighbor pairs that were otherwise physically identical but were presented in different font sizes and types (Nakayama et al., 2011, 2014).

Method

Participants. Forty-four Japanese-English bilinguals from Waseda University (Tokyo, Japan) participated in this experiment. Their mean TOEIC score was 858 (range = 800–960). None of the participants had participated in any of the previous experiments. All of the participants had normal or corrected-to-normal vision.

Stimuli. The stimuli were the same as those used in Experiments 1 and 2.

Procedure. The procedure was the same as in Experiments 1 and 2, except that targets were presented in lower-case letters. To minimize physical overlap, primes and targets were presented in a different font types (Cambria and Courier New, respectively) with the target's physical size being about 20% larger than the prime's size.

Results

The data from two participants were removed because of high error rates (>25%). Data from one participant was also removed as this participant identified as a simultaneous bilingual with native level fluency in both Japanese and English. Those participants were replaced by additional participants while maintaining the counterbalancing of the presentation lists. Response latencies faster than 300 ms or slower than 1,800 ms were considered outliers and removed from the analyses (only one data point in the nonword data). The data were analyzed in the same way as in Experiments 1 and 2. Table 5 shows mean RTs and error rates from Experiment 5.

Word targets. For response latency, there was a significant main effect of prime type, $F_s(1, 43) = 12.84$, $p < .001$, $MSE = 1201.6$, $\eta_p^2 = .23$; $F_i(1, 63) = 8.31$, $p < .01$, $MSE = 2891.4$, $\eta_p^2 = .12$. Again, the direction of the priming effect was facilitory (+19 ms). There was no significant main effect of prime lexically, both Fs < 1. There also was no interaction between prime lexicality and prime type, $F_s(1, 43) = 1.34$; $F_i < 1$, although, numerically, the size of priming effect was larger from word neighbors than from nonword neighbors (+26 ms and + 12 ms). For errors, there was a marginally significant main effect of prime type in the subject analysis, $F_s(1, 43) = 2.94$, $p = .09$, which was not significant in the item analysis, $F_i(1, 63) = 2.65$, $p > .10$. The main effect of prime lexicality was not significant, both Fs < 1, nor was the interaction between prime lexicality and prime type, both Fs < 1.

Nonword targets. For response latency, the main effect of prime type was significant, $F_s(1, 43) = 32.00$, $p < .001$, $MSE = 933.1$, $\eta_p^2 = .43$; $F_i(1, 63) = 13.81$, $p < .001$, $MSE = 3422.3$, $\eta_p^2 = .43$. Nonword targets primed by orthographic neighbors were responded to significantly faster than nonwords primed by unrelated primes. There was no main effect of prime lexicality, both Fs < 1, nor was there an interaction between prime type and prime lexicality, both Fs < 1. For errors, the main effect of prime type was not significant, $F_s < 1$; $F_i(1, 63) = 1.64$, $p > .20$. The main effect of prime lexicality was also not significant, both Fs < 1. The two-way interaction between prime type and prime lexicality was marginally significant, $F_s(1, 43) = 3.30$, $p = .08$, $F_i(1, 63) = 2.88$, $p = .09$.

Power issues. For Experiments 5, effect sizes of neighbor priming effects in L2 (prime type) were determined based on the results of the present Experiments 1 and 4. The average effect sizes [η_p^2] for neighbor priming effects were .22 and .07 for subjects and items, respectively. Assuming similar effect sizes across experiments (i.e., if one assumes that the effects are not affected by the letter cases of targets), the required sample sizes were calculated to be 30 subjects and 107 items. As such, our sample size of 44 subjects was large enough to allow us sufficient power but our sample size of 64 items was not. Nonetheless, the critical results were successfully replicated.

Table 5
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates for Lower-Case Word and Nonword Targets Primed by Word Neighbors, Unrelated Words, Nonword Neighbors, and Unrelated Nonwords in Experiment 5

Target	Word primes		Nonword primes	
	Reaction time	Errors	Reaction time	Errors
Word targets				
Neighbor	644	12.9%	655	11.8%
Unrelated	670	10.7%	667	10.4%
Priming	+26	−2.2%	+12	−1.4%
Nonword targets				
Neighbor	695	10.7%	688	8.0%
Unrelated	718	9.9%	717	11.2%
Priming	+22	−.8%	+29	+3.2%

Discussion

When the targets were presented in lower-case letters, overall response latencies were much shorter (by more than 50 ms) than when the same targets were presented in upper-case letters in Experiment 1. This result suggests that lower-case targets are indeed much easier to process for Japanese-English bilinguals. However, even though bilinguals supposedly did not need to rely on sublexical level activation to make lexical decisions to the English targets in this experiment, the pattern of priming effects did not change: orthographic neighbors significantly facilitated target identification regardless of the lexicality of the primes. That is, once again, the bilinguals did not show any signs of distinguishing word neighbor primes from nonword neighbor primes. The results of Experiment 5 therefore did not support the idea that the processing difficulty associated with upper-case English targets made participants rely heavily on letter-level information, allowing word neighbor primes to aid in identifying targets by aiding in identifying letters.

Experiment 6

Up to now, our results have suggested that lexical competition does not operate in the L2 lexicon of different-script bilinguals. The prior experiments have all involved masked priming lexical decision tasks. The idea to be examined in Experiment 6 is that the L2 word recognition process does involves lexical competition but that processing operates sufficiently slowly/weakly that the impact of competition will not show up in typical masked priming experiments. That is, for native readers, the lateral inhibition mechanism may be so developed that its effects can occur fast and automatically, allowing for inhibition effects in a masked priming situation.

In fact, L1 English readers not only show evidence for lexical competition with masked primes but also with briefly presented unmasked primes (e.g., Burt, 2009; Massol, Molinaro, & Carreiras, 2015), indicating that regardless of whether or not the competitor is consciously perceived, orthographic neighbor primes affect target identification in similar ways. In contrast, for Japanese-English bilinguals, although this competition process is certainly not fully developed in their English lexicon, signs of it may emerge if there is conscious awareness of the competitor. To test this possibility, in Experiment 6, a prime duration of 175 ms was employed. We chose this prime duration following Burt's results in which inhibitory neighbor priming effects were reliably observed with this prime duration for her L1 English readers (Burt, 2009).

Method

Participants. Fifty-two Japanese-English bilinguals from Waseda University participated in this experiment. None of the participants had participated in any of the previous experiments. Their mean TOEIC score was 854 (range = 730–960). All of the participants had normal or corrected-to-normal vision.

Stimuli. The same set of stimuli used in Experiments 1 and 2 was used.

Procedure. The procedure was the same as in Experiments 1 and 2, except that primes were presented for 175 ms.

Results

The data from four participants were removed because of high error rates (>25%). They were replaced by different participants while maintaining the counterbalancing of the lists. Response latencies faster than 300 ms or slower than 1,800 ms were considered outliers and removed from the analyses (0.4% of the word data, and 1.2% of the nonword data). The remainder of the data was analyzed identically to the data in Experiments 1, 2 and 5. Table 6 shows mean RTs and error rates from Experiment 6.

Word targets. For response latency, the main effect of prime type was not significant, $F_s(1, 51) = 2.35$, $p > .10$; $F_s(1, 63) = 3.10$, $p = .08$. The main effect of prime lexicality was also not significant, $F_s(1, 51) = 2.25$, $p > .10$; $F_i(1, 63) = 3.43$, $p = .07$. Critically, however, there was a significant Prime Type × Prime Lexicality interaction, $F_s(1, 51) = 6.78$, $p < .05$, $MSE = 2970.5$, $\eta_p^2 = .12$; $F_i(1, 63) = 4.49$, $p < .05$, $MSE = 6771.4$, $\eta_p^2 = .07$. Follow-up analyses of the interaction showed that word neighbor primes produced a null priming effect with a small inhibitory trend (743 ms vs. 735 ms), both *t*s < 1. In contrast, nonword neighbor primes produced a significant facilitory effect (710 ms vs. 741 ms), $t_s(51) = 2.80$, $p < .01$, $SEM = 11.2$; $t_i(63) = 2.90$, $p < .01$, $SEM = 12.3$.

In the error data, the main effect of prime type was significant in the subject analysis and that effect approached significance in the item analysis, $F_s(1, 51) = 4.02$, $p = .05$, $MSE = 78.6$, $\eta_p^2 = .07$; $F_i(1, 63) = 3.58$, $p = .06$, $MSE = 108.7$, $\eta_p^2 = .05$. There was no main effect of prime lexicality, both *F*s < 1. Consistent with response latency data, the interaction between prime lexicality and prime type was significant, $F_s(1, 51) = 6.09$, $p < .05$, $MSE = 51.8$, $\eta_p^2 = .11$; $F_i(1, 63) = 5.54$, $p < .05$, $MSE = 70.2$, $\eta_p^2 = .08$. Word neighbor primes produced a significant inhibitory effect (14.3% vs. 9.4%), $t_s(51) = 2.84$, $p < .01$, $SEM = 1.7$; $t_i(63) = 2.75$ $p < .01$, $SEM = 1.8$, whereas nonword neighbor primes produced a null effect, both *t*s < 1.

Nonwords targets. The only effect that approached significance was the main effect of prime lexicality in the subject analysis of response latencies, $F_s(1, 51) = 3.44$, $p = .07$. No other effects were observed for response latency or for errors (all other *F*s < 1.9, *p*s > .10).

Power issues. For Experiment 6, the effect sizes of neighbor priming effects in L2 (prime type) were determined based on the results of the present Experiments 1, 4 and 5. The average effect sizes were .22 and .09 for subjects and items, respectively. Assuming similar effect sizes across experiments (i.e., if one assumes that the effects are not affected by SOA, Stimulus Onset Asynchrony), the required sample sizes were calculated to be 30 subjects and 82 items, where our sample sizes were 54 subjects and 64 items. Therefore, Experiment 6 did not have enough items to achieve the desired power of .80 in the item analysis. Nonetheless, based on the assumption that the effect size for the item analysis is .09, the estimated power in Experiment 6 would be .70 (based on having 64 items). Although this value is slightly lower than the desired power, it is still quite high.

Table 6
Mean Lexical Decision Latencies (in Milliseconds) and Error Rates for Word and Nonword Targets Primed by Word Neighbors, Unrelated Words, Nonword Neighbors, and Unrelated Nonwords in Experiment 6 (175 Ms Prime Duration)

	Word primes		Nonword primes	
Targets	Reaction time	Errors	Reaction time	Errors
Word targets				
Neighbor	743	14.3	710	11.7
Unrelated	735	9.4	741	11.7
Priming	−8	−3.9	+31	0
Nonword targets				
Neighbor	819	10.9	800	10.7
Unrelated	824	9.6	816	10.6
Priming	+5	−1.3	+16	+.1

Discussion

In Experiment 1, when primes were presented for 67 ms, a clear facilitory priming effect was observed for word neighbor prime-target pairs. When the primes were presented for 175 ms in Experiment 6, the facilitory effect was diminished and a trend toward inhibition appeared, with that trend being significant in the error analyses. In contrast, the priming effects for nonword neighbor pairs did not seem to be affected by prime duration as the sizes of priming effects for the nonword neighbor pairs were very similar across all the experiments involving those prime-target pairs. Thus, SOA influenced the patterns of priming only when the neighbor primes were words (i.e., their representations are found in the bilinguals' lexicon). The results of Experiment 6, therefore, were consistent with the idea that lexical competition does operate in the L2 lexicon of different-script bilinguals, but it does so only when processing of the word neighbor prime can go on for a sufficiently long time. Further, even in that situation, the inhibition effect is not strong in comparison to effects observed for L1 English readers. Specifically, whereas the effect in Experiment 6 was only significant in the error data, in the 175 prime duration condition of Burt's (2009) experiments with L1 English readers, inhibitory word neighbor priming effects in the latency data were noticeably larger (e.g., 10–40 ms effects).

General Discussion

In the present research, six experiments were conducted to examine whether lexical competition plays a role when unbalanced different-script bilinguals read L2 words. The results of the six experiments are as follows. In Experiment 1, Japanese-English bilinguals produced a facilitation effect for English targets that were preceded by masked neighbor primes and this effect was not modulated by the lexicality of the primes. In Experiment 2, L1 English readers, in contrast, produced an inhibitory effect from word neighbor primes and a null effect from nonword neighbor primes. In Experiment 3, Japanese-English bilinguals, whose proficiency in English was virtually identical to that of the participants in Experiment 1, showed significant L2-L2 repetition priming effects and L2-L1 noncognate translation priming effects, indicating that readers at that level of proficiency are able to process masked L2 primes sufficiently well to activate the primes' lexical and/or conceptual information. In Experiment 4, using a single set of bilinguals, it was demonstrated that the same critical L2 primes can simultaneously show facilitory L2 neighbor priming (i.e., the effect observed in Experiment 1) and an L2-L1 translation priming effect (an effect also observed in Experiment 3 which implies that L2 primes are processed to the conceptual level). Experiment 5 showed that the facilitory neighbor priming effects remained even when English targets were presented in lower-case letters, indicating that the effects observed in Experiments 1 and 4 were not due to the use of orthographically unfamiliar upper-case English targets. Finally, in Experiment 6, using a 175 ms prime duration, word neighbor primes were shown to produce a small inhibition effect (although it was only significant in the error data) rather than the facilitation effects observed in the previous experiments while, at the same time, nonword neighbor primes produced the same pattern of facilitation as shown in the previous experiments. That is, in this situation, bilinguals did process word and nonword neighbor primes differently.

Based on the overall data pattern, it is clear that lexical competition does not play a major role when different-script bilinguals read L2 English words unlike when L1 English readers process L1 words or when same-script bilinguals process L2 words. For different script-bilinguals in masked priming situations, orthographic neighbor primes do appear to be able to activate lexical representations of orthographically similar words (while, at the same time, activating the conceptual representation of the prime itself), facilitating processing of those neighbor words. Lexical competition, as indexed by inhibition effects from word neighbor primes, however, appears to play no role unless participants have additional time to process those primes. That is, for different-script bilinguals, more prime processing time and/or conscious appreciation of the competitor is needed for there to be any evidence of lexical competition.

Individual Differences in Neighbor Priming Effects

In the present experiments, Japanese-English bilinguals who were proficient enough to produce L2-L1 translation priming did not show inhibitory priming effects from word neighbor primes unless given additional time to process the prime. Given the documented ability of these types of individuals to process English words, the obvious question is, why? Recent studies, some of which involve monolinguals, appear to suggest an answer. That is, what is now becoming clear from those studies is that there are individual differences in how masked orthographic primes affect L1 target identification (e.g., Adelman et al., 2014; Andrews & Hersch, 2010; Andrews & Lo, 2012). For example, Andrews and Lo (2012) reported that L1 English readers with higher general English proficiency (participants who had higher scores on reading comprehension, vocabulary and spelling tests), showed stronger inhibitory priming effects from word neighbor primes and stronger facilitory priming effects from nonword neighbor primes than lower proficient ones (but see Adelman et al., 2014). According to Andrews and Lo, one of the skills L1 English readers with higher general English proficiency have is a higher level of lexical precision; they are more accurate in analyzing the constituent letters of a printed word. Thus, when a word neighbor prime is presented, they can correctly activate its lexical representation much faster and more efficiently. The result is better activation of the prime and a larger inhibitory priming effect for neighbor targets. When a nonword prime is presented, they are less likely to erroneously activate any single word neighbor and, hence, target identification is not strongly affected by lexical competition. As a result, skilled readers produce larger facilitation effects from nonword neighbor primes on the basis of those primes' orthographic similarity to their targets.

It would seem that these same principles could be applied to our Japanese-English bilinguals who were dominant in L1 Japanese and learned L2 English as a second language. It was likely that their English, although quite proficient for L2 readers, was much weaker than that of the less proficient L1 English readers tested in Andrews and her colleagues' studies, especially given the fact that those L1 readers were "less proficient" in a relative sense (i.e., within a population of university students in Australia). As a result, it is reasonable to assume that Japanese-English bilinguals did not have a high level of lexical precision. Hence, a briefly presented, masked L2 prime would not have had the ability to engage the system to a sufficient degree to produce competition/inhibition effects even though it would have been able to activate the lexical representations of orthographically similar targets.

This type of analysis suggests that L2 proficiency should be at least somewhat correlated with lexical precision and, therefore, one might expect to see some individual differences among our participants. Specifically, although the priming effect from word neighbor primes was facilitory overall, some of the very high proficient bilinguals might show a trend toward inhibition because their L2 lexical processing would be more precise. The relationship between L2 proficiency and facilitory priming effects from nonword neighbors would go in the opposite direction; facilitation would be larger for higher proficient bilinguals.

To examine individual differences in L2 neighbor priming effects, we analyzed the results of Experiment 1 using linear mixed effects models. In these analyses, raw RTs were inverted to meet the Gaussian distributional assumption of the model and were used as the dependent variable. Prime type was contrast coded by 0.5, and −0.5, and the individuals' TOEIC scores were centered around the mean. Prime type, TOEIC score, and their interaction were treated as fixed factors, and by-subject and by-item intercepts and slopes for prime type were treated as random factors (the maximal model, Barr, Levy, Scheepers, & Tily, 2013). Priming effects from word and nonword neighbors were analyzed separately.

The left and right panels of Figure 1, respectively show the word and nonword neighbor priming effects plotted as a function of L2 proficiency. As can be seen in the two figures, there is little evidence that the patterns of priming effects were modulated by L2 proficiency. That is, even though there was some hint that the facilitation effect for word primes was shrinking as proficiency increased, there was no interaction between prime type and TOEIC scores for targets primed by word neighbors ($t < 1$), or for targets primed by nonword neighbors ($t < 1$). Consistent with the ANOVA analyses, the linear mixed effects analysis showed a significant facilitory effect from neighbor primes, $t = -3.38$, $p < .001$ and faster RTs for more highly proficient bilinguals, $t = -2.54$, $p < .05$. The same pattern of results was observed for nonword prime-target pairs (a significant facilitory priming effect, $t = -3.61$, $p < .001$ and faster RTs for more highly proficient bilinguals, $t = -3.89$, $p < .001$).

Because Japanese-English bilinguals showed priming patterns that were similar to L1 readers in Experiment 6 (i.e., a prime lexicality effect), we also analyzed the data from that experiment in order to see whether any individual difference pattern could be detected (see Figure 2). The left panel seems to show that more proficient bilinguals did produce larger inhibition effects from word neighbors with the right panel suggesting that those same individuals showed smaller facilitation effects from nonword neighbors. However, statistically, there was no hint of interaction between priming and TOEIC score for either word neighbor primes or nonword neighbor primes, both $ts < 1$ (nor was there a main effect of prime type $t < 1$). Overall what the results of this analysis showed was a pattern consistent with what the initial ANOVA showed, a significant main effect of L2 proficiency, $t = -2.12$ and a significant Prime Lexicality × Prime Type interaction, $t = 3.26$, $p < .001$.

Essentially, these individual difference analyses showed that the patterns of neighbor priming effects were not modulated by L2 proficiency and such was the case whether primes were masked or visible. It seems unlikely that the null interactions reflected a generic range restriction in our data, as higher L2 proficiency was significantly associated with faster responding to L2 targets in both sets of analyses. However, it is possible that a high TOEIC score (or a high level of L2 English proficiency) is not a clear indicator of a high level of lexical precision. Possibly, individual differences could have been found if we had used a presumably more direct measure of lexical precision, such as bilinguals' spelling ability, as a predictor (Andrews & Hersch, 2010). Alternatively, we might have discovered that even our best L2 readers did not have a level of lexical precision anywhere near as high as Andrews and Lo's (2012) more "precise" skilled readers. Therefore, given that some bilinguals tested in Experiment 1 reported having a virtually perfect score (990/990) on the TOEIC and many participants reported having scores within the top 3% of the TOEIC distribution, a reasonable conclusion would be that a measurable lexical competition process in L2 may be extremely difficult to develop for different-script bilinguals, especially one that can be observed under masked priming conditions.

Converging Evidence for Facilitory Word Neighbor Priming Effects in L2

In the present experiments, L2 word neighbor primes consistently facilitated L2 target identification. Recently, Qiao and Forster (2017) using relatively long English words (6–8 letters in length) also reported that Chinese-English bilinguals showed very large facilitory priming effects (i.e., 44–61 ms) for targets primed by word neighbors (e.g., protect-PROJECT). In those authors' previous work (Qiao & Forster, 2013), the same set of word neighbor pairs produced no priming effects for L1 English speakers (+11 to −1 ms difference). Essentially, what this latter result indicates is that target length is also an issue in whether an inhibition effect emerges or not. When longer targets are used as stimuli, there is hardly an evidence of inhibition effects (e.g., see also Forster, 1987; Forster & Veres, 1998). What is important for present purposes, however, is that Qiao and Forster's (2013, 2017) results virtually parallel the results found in the present Experi-

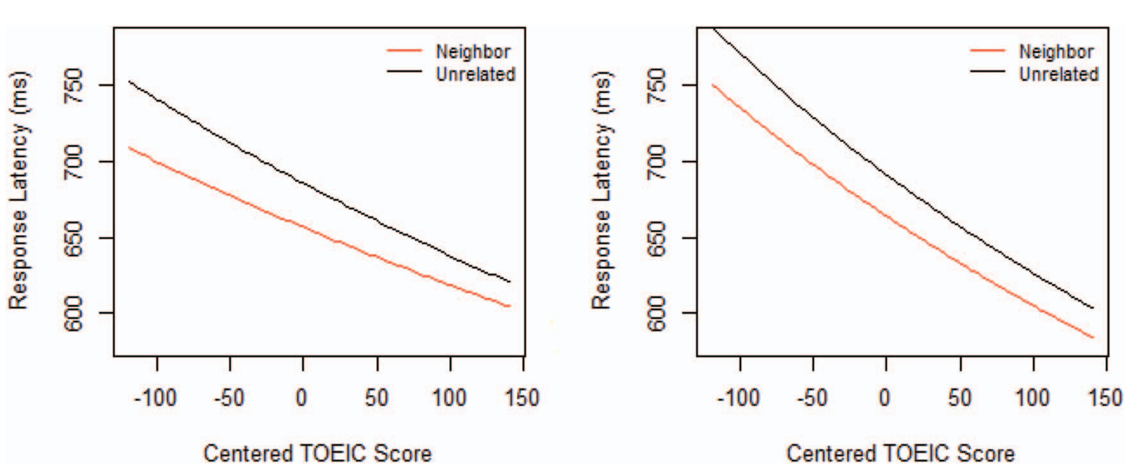

Figure 1. Response latencies to English targets preceded by word neighbor and unrelated primes (the left panel) and by nonword neighbor and unrelated primes (the right panel) as a function of bilinguals' English proficiency in Experiment 1 (67 ms prime duration). See the online article for the color version of this figure.

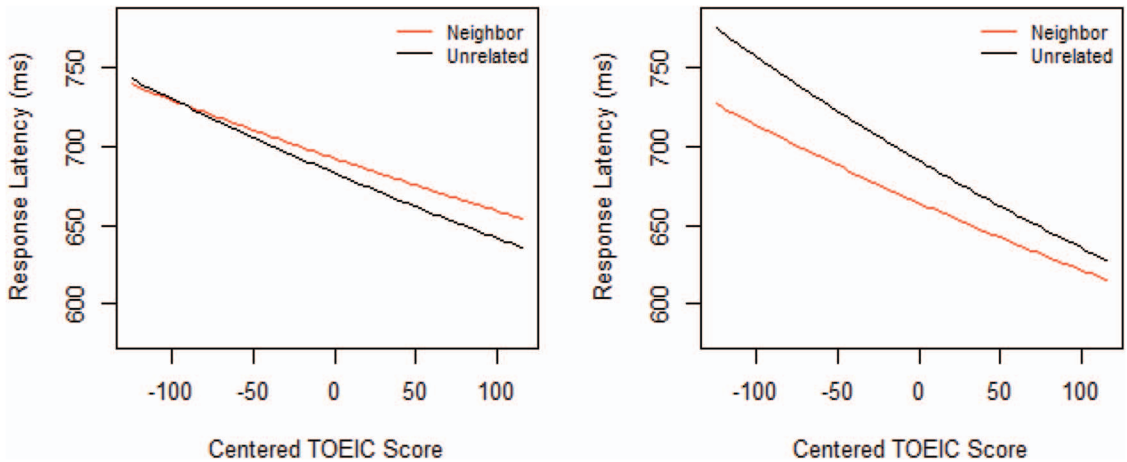

Figure 2. Response latencies to English targets preceded by word neighbor and unrelated primes (the left panel) and by nonword neighbor and unrelated primes (the right panel) as a function of bilinguals' English proficiency in Experiment 6 (175 ms prime duration). See the online article for the color version of this figure.

ments 1 and 2 in which we used short word neighbor pairs: word neighbor primes (e.g., pity-CITY) produced significant facilitation for Japanese-English bilinguals (+22 effect) and significant inhibition for L1 English readers (−21 ms effect). To supplement the claim that this difference is real, we carried out an ANOVA contrasting the + 22 ms effect for the bilinguals and the −21 ms effect for L1 English readers found in our Experiments 1 and 2. Those effects were statistically different from each other, $F_s(1, 90) = 17.32$, $MSE = 1179.9$, $p < .001$; $F_i(1, 63) = 9.26$, $MSE = 4790.2$, $p < .01$. Although Qiao and Forster never statistically tested for a group difference in their two priming patterns, the very large numerical priming effect difference suggests that their interaction was also likely to have been significant.

Qiao and Forster (2013, 2017) also found a sharp difference between L1 English readers and Chinese-English bilinguals when they examined how newly learned English words became integrated into their English lexicons. In those studies, L1 English readers and Chinese-English bilinguals were taught the same set of novel English words. The "novel" English items were created by changing one letter of a base English word (e.g., baltery from battery, clight from flight, etc.). To promote lexicalization, each novel word was learned along with its definition and a picture (e.g., *clight* is "a rare sea animal that is a kind of worm") in multiple sessions spaced over a few weeks. By the end of the training sessions, participants reacted to the previously (nonword) novel items as real words very quickly in a lexical-decision task suggesting that the items had been integrated into the participants' lexicons. Then, in the final experimental session, the novel words served as neighbor primes in a masked priming lexical-decision task (e.g., clight–FLIGHT). For the L1 readers, no priming occurred from the novel word neighbors (a 6-ms difference). As mentioned above, null priming from long word neighbor prime is a typical finding in L1 priming studies. However, the same novel word neighbor primes produced a large facilitation effect for Chinese-English bilinguals (a 53-ms effect).

Because Qiao and Forster (2017) did not examine the question, one cannot know whether their Chinese-English bilinguals were capable of processing masked English primes to the lexical level. Therefore, the facilitation from word neighbor primes observed for their Chinese participants could have been due to sublexical level activation. Although our Experiment 1 also suffered from the same ambiguity, the present Experiments 3 and 4 made it clear that word neighbor primes do facilitate target identification in L2 even when prime processing does not end at the letter level. The results of the present experiments and those of Qiao and Forster together suggest that even the most fluent different-script bilinguals process orthographically similar L2 words somewhat differently from how both L1 readers' process L1 words and same-script bilinguals (Bijeljac-Babic et al., 1997) process L2 words, at least during the early moments of word processing.

In an attempt to explain why different-script bilinguals show facilitory priming effects from orthographic neighbors, Qiao and Forster (2017) argued that the L2 words are represented qualitatively differently from L1 words, specifically, L2 words are represented in episodic memory and L1 words are represented in lexical memory (Witzel & Forster, 2012). Because lexical competition is, by definition, a process that is assumed to occur within lexical memory, if L2 words are represented only in episodic memory, L2 orthographic neighbors would not be expected to behave similarly to lexically represented (L1) words. Specifically, L2 orthographic neighbors would not engage lexical competition. Further, if one accepts the idea that L2 words are episodically represented, it seems to make good sense that primes that are sufficiently similar to their targets would help in identifying those targets.

What should also be noted here is that Witzel and Forster (2012)'s hypothesis maintains that L2 words will forever be represented in episodic memory for unbalanced bilinguals. This hypothesis would explain why masked neighbor priming effects were equally facilitory across varying L2 proficiency levels in the present Experiments 1 and 6, because under this view, the patterns of neighbor priming effects would not be determined by anything lexical in nature (such as lexical precision).

Nonetheless, the idea that L2 words are only episodically represented does face problems from the present results. In particular, the L2-L1 translation priming results observed in Experiments 3 and 4 strongly suggest that our bilinguals store L2 words in lexical memory. According to Witzel and Forster (2012), null L2-L1 translation priming in a lexical-decision task is a critical prediction of their Episodic L2 hypothesis. A null L2-L1 translation priming effect is a result that is often found in the literature (Chen, Zhou, Gao, & Dunlap, 2014; Gollan et al., 1997; Jiang, 1999, Experiment 2–5; Jiang & Forster, 2001; Witzel & Forster, 2012; Nakayama et al., 2013; Wang, 2013, Experiment 1; Xia & Andrews, 2015). However, as the present data show, L2-L1 translation priming does emerge when the bilingual's proficiency level is sufficiently high (see also Nakayama et al., 2016, 2017), indicating that one would have to conclude that the bilinguals showing those effects must store at least some L2 words in lexical memory.

What is potentially also relevant to the Episodic L2 hypothesis is the fact that our bilinguals did show a reasonably strong trend toward inhibition on response latencies and a significant effect on error rates from word neighbor primes when a long SOA was used (Experiment 6). This result supports the idea that lexical competition may operate to at least a small degree in the L2 lexicon of different-script bilinguals, although it is not entirely clear why there was not even a suggestion that L2 proficiency modulated the priming patterns. And, as noted previously, the Episodic L2 position does predict that even same-script bilinguals should not show inhibition effects in cross-language word neighbor priming tasks, a prediction that is falsified by the results of Bijeljac-Babic et al. (1997). Therefore, at present, Forster and colleagues' Episodic L2 hypothesis does not appear to offer much promise for explaining priming effects in L2 in general. However, the (previously noted) evidence in support of that hypothesis does reinforce the claim offered here, that different-script bilinguals represent L2 words somewhat differently from how those words are represented by both same-script bilinguals and L1 readers, with that evidence further suggesting that episodic memory may play more than a minor role in how bilinguals represent L2 words.

How Would the L2 Lexicon Be Similar to a Developing L1 Lexicon?

In thinking about what characterizes the L2 representation of different-script bilinguals, one might wonder whether those representations are similar to the lexical representations of developing readers of that language. Therefore, another way to look for explanations for the present data would be to consider whether different-script bilinguals deal with orthographic similarities of L2 words similarity to how developing L1 readers deal with their L1 words.

Some previous studies indicate that there may be some similarities. For instance, Castles, Davis, Cavalot, and Forster (2007), using a masked priming lexical-decision task (a 57-ms prime duration), reported that 3rd-grade elementary schoolchildren produced facilitory priming effects for L1 targets primed by high-N nonword neighbors (e.g., rlay-PLAY). High-N nonword neighbor primes were not expected to, and did not, produce any priming effects for adults in the same experiment. This contrast is similar to the results of present Experiments 1 versus 2, in which Japanese-English bilinguals showed significant facilitation from medium-N nonword primes whereas L1 English readers showed a null effect from the same primes (e.g., lity-PITY). Interestingly, Castles et al. tested the same children 2 years later and found that the then 5th-grade children no longer showed facilitation from those nonword neighbor primes. The authors argued that this age-related difference was the result of the children's vocabulary sizes growing during the intervening two years. Of necessity, the lexical processing of words became more precise allowing the students to detect small differences because the system needed to distinguish the correct word from many other orthographically similar words that had been acquired over that two year period.

Following the results of Castles et al. (2007), one may be tempted to suggest that the L2 lexicon of different-script bilinguals may be organized similarly to the L1 lexicon of 3rd-grade elementary schoolchildren, with the implication that the zero to very weak lexical competition for different-script bilinguals could have been due to their small English vocabulary (i.e., few lexical competitors lead to little lexical competition).[5] Indeed, some support for this idea would come from the fact that Andrews and Hersch (2010) have reported that low-*N* word targets did not show inhibition effects from word primes.

There are, however, a couple of reasons to be skeptical of this as a possible explanation of the present data. First, although our word targets did have moderate *N* sizes according to standard calculations, *N* sizes that probably, at least slightly, overestimated their true neighborhood sizes for our Japanese-English bilinguals, those individuals probably knew far more English words than 3rd-grade L1 English-speaking children. We have previously given an English vocabulary test (the Nelson-Denny vocabulary subtest) to Japanese-English bilinguals drawn from the same population as those in the present studies and learned that their average English vocabulary size was equivalent to L1 English-speaking 10th-grade students (Nakayama et al., 2013). Thus, Japanese-English bilinguals in the present experiments were very likely to have had somewhat larger English vocabulary sizes than even those of 5th-grade L1 English-speaking children. Second, in previous research, when the relative prime-target frequency relation manipulation has been strong (i.e., the primes were much higher in frequency than the targets as was the case for our stimuli although not for Andrews & Hersch's, 2010, stimuli), low-*N* target words still showed inhibition effects (e.g., Davis & Lupker, 2006; Nakayama et al., 2008).

The more likely conclusion, therefore, is that, although our bilinguals showed similar patterns of priming effects as Castles et al. (2007)'s younger L1 English speaking children, this parallel was not likely due to their small vocabulary sizes in English. That claim does not, of course, reject the idea that the L2 lexicon is organized similarly to L1 lexicon of developing readers. For example, it is possible that lexical tuning is related to other factors than vocabulary sizes and that bilinguals and developing readers may have similar abilities along those dimensions. In fact, vocabulary growth may not be a key factor for the development of fine lexical tuning, because effective *N* size, the actual number of neighbors of a prime known by a participant did not predict the changes in the patterns of priming effects from high *N* nonword neighbors (e.g., that the facilitation for rlay–PLAY type pairs eventually diminishes - Bhide, Schlaggar, & Barnes, 2014). For Bhide et al.'s participants, it was chronological age that was the strongest predictor. Physical maturation itself, however, cannot

[5] We thank an anonymous a reviewer for suggesting this idea.

lead to fine-grained lexical tuning because if it did, our bilinguals would show adult style neighbor processing. It is therefore important to look for other similarities between the two groups that may explain their similar patterns of neighbor priming effects (e.g., more exposure to the print, greater experience with writing letters/words, higher spelling ability, among many other possibilities).

Conclusion

In the present experiments, we examined whether lexical competition operates during the visual word recognition process of different-script bilinguals when they are reading L2 words. Our results suggested that automatic lexical competition is unlikely to have developed for those bilinguals, regardless of their proficiency. When the prime/competitor is clearly visible, however, there does appear to be some lexical competition, although the competition appears to operate at much reduced level. As such, different-script bilinguals appear to deal with orthographic similarities among L2 words somewhat differently than L1 readers of the language and also than same-script bilinguals. Additional research is needed to determine what factors are contributing to this difference and whether it reflects quantitative versus qualitative differences in how their L2 lexicon is organized.

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