Does Lexical Competition Play a Role in Word Recognition of Non-Roman Script Language? A Test for an Inhibitory Neighbor Priming Effect with Japanese Katakana and Kanji Words

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Abstract

Previous masked priming studies have reported that lexical decision latencies are slower when a word target is primed by a higher-frequency neighbor (e.g., blue-BLUR) than when the same target is primed by an unrelated word of equivalent frequency (e.g., care-BLUR). These results are consistent with activation-based accounts of lexical processing and suggest that lexical competition plays an important role in visual word recognition in Indo-European languages such as English, French, and Dutch. The present research examined whether such a mechanism also operates for visual word recognition in the Japanese language. The results suggest lexical competition for Japanese Katakana words: response times for targets primed by high-frequency words were significantly slower than response times for targets primed by similar frequency words. In contrast, the inhibitory neighbor priming effect was observed only for error rates for Japanese Kanji words. The weak evidence of lexical competition was best explained by assuming that the inhibitory effect was counteracted by a facilitory priming effect due to orthographic or morphological overlap of Kanji neighbors. Taken together, the results of present research suggest that lexical competition is an important component of word recognition processes not only for Indo-European languages but also for languages that do not use the Roman alphabet.

Chapter 1.General Introduction of the Present Study

Theoretical and Empirical Background

The idea that visual word recognition is driven by a competitive activation process has a long history. A considerable number of studies have provided support for this view over the past three decades (e.g., Carreiras, Perea, & Grainger, 1997; Davis & Lupker, 2006; Huntsman & Lima, 1996, 2002; Janack, Pastizzo, & Feldman, 2004; Grainger, O'Regan, Jacobs, & Segui, 1989; Grainger & Jacobs, 1996; Grainger & Segui, 1990; Nakayama, Sears, & Lupker, 2008; 2011; Perea & Pollatsek, 1998). The competition principle itself is incorporated in most activation-based models; for example, the interactive-activation model (McClelland & Rumelhart, 1981), the multiple read-out model (Grainger & Jacobs, 1996), and more recent variants (e.g., Davis, 2003). These models assume there is a competition among activated lexical representations during the processing of a word. Specifically, these models assume that the lexical representation of a presented word and those of orthographically similar words (i.e., the word's "neighbors") are activated simultaneously early in processing, and that, once activated, these lexical representations compete with and inhibit one another. Thus, the lexical representation of the presented word is assumed to be selected only after the competition is resolved. Figure 1 shows the architecture of the interactive-activation model (McClelland & Rumelhart, 1981).

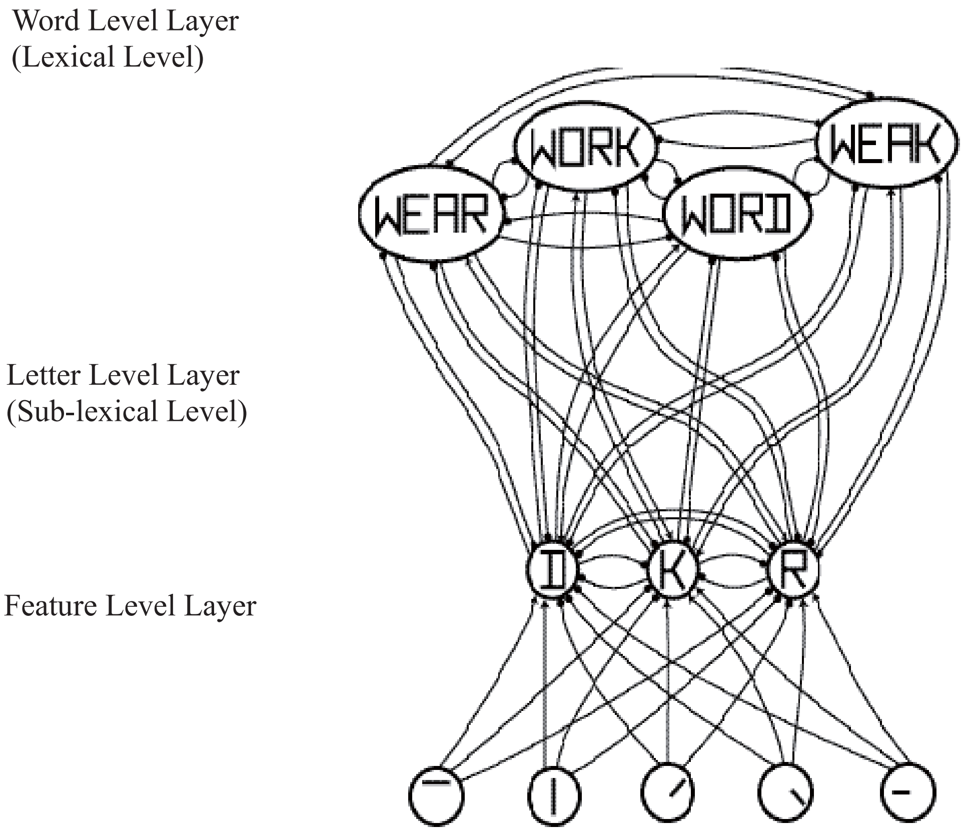

Figure 1. Architecture of the Interactive Activation Model.

This model assumes that word identification involves the interactive processing of three levels of feed-forward and feed-back connections (i.e., feature, letter, and word levels). Across letter-level and word-level layers, representational units are linked via both excitatory and inhibitory connections. Within letter-level and word-level layers, there is only inhibitory connection among representational units. The inhibitory connections within a layer are referred to as lateral inhibition. The inhibitory effect of orthographic neighbors on target identification is thought to reflect the lateral inhibition at the word level layer.

Empirical tests of these models have typically adopted Coltheart, Davelaar, Jonasson, and Besner's (1977)'s definition of an orthographic neighbor. An orthographic neighbor is a wordthat shares all, but one of the target word's letters (e.g., *case*, *ease*, and *vast* are all orthographic neighbors of *vase*). Recent studies show that this definition is too narrow and that the lexical units of other visually similar words are also relevant to the process (e.g., words that are of different lengths, words that differ at two letter positions, words that share the initial syllable;De Moor & Brysbaert, 2000; Janack, et al. 2004; Carrieras & Perea, 2002, respectively).

Regardless of the exact definition of an orthographic neighbor, all of the models suggest that lexical competition is affected by the relative frequencies of a word and its neighbors. Words with higher-frequency neighbors experience more competition/inhibition because higher-frequency neighbors have higher resting levels of activation. This means that higher-frequency neighbors inhibit their competitors much earlier and morestrongly when they are presented. Words without higher-frequency neighbors, on the other hand, experience much less competition/inhibition and, as a consequence, the lexical-selection process of these words is less affected by the presence of lower-frequency neighbors.

These inhibitory effects support the notion that each word has a discrete local representation, and thus, do not coincide with parallel distributed processing (PDP) models (e.g., PDP models, Seidenberg & McClelland, 1989; Plaut, McClelland, Seidenberg, & Patterson, 1996). In PDP models (see Figure 2), a word is represented by a pattern of activation over units for orthographic, phonological and semantic features rather than local units for each word. As a result, a prime is not thought to have a lexical representation to preactivate, and hence, there is no competition between activated lexical representations. PDP models do not offer an obvious explanation for how a word prime could delay processing of an orthographically-similar target. In fact, the most straightforward prediction of the PDP models is that neighbor primes produce facilitory priming effects by activating sets of features that the prime and target share in common (i.e., orthographic, phonological, and semantic features). The existence of lexical competition, therefore, does not only document that the lexical competition plays a significant role in visual word recognition, but it also has an important theoretical implication in that it strongly supports the view that each word has its own local representation, and that representation of a word is not merely a pattern of activation over orthographic, phonological and semantic features a word embodies.

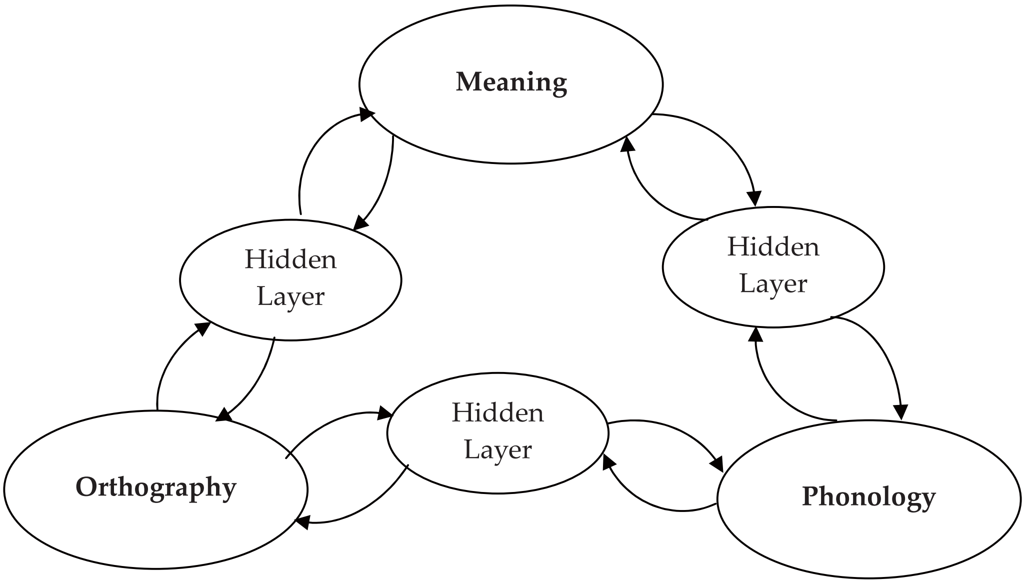

Figure 2. The Architecture of Parallel Distributed Models

This class of model assumes that the word identification involves interactive processing of feed-forward and feed-back connections between three levels of lexical features (orthography, phonology, and meaning). This class of model also assumes that between each lexical feature, there exists a hidden unit, where information that is activated within each unit is calculated in a non-liner manner before sending information to a different unit.Similar to the activation-based models, this class of model assumes that each unit is connected via both excitatory and inhibitory signals and that the information is processed interactively among such units. Unlike the activation-based models, however, this class of model assumes that the representation of a word is stored distributively across these units. This model does not assume that a specific local representation corresponds to the word.

Masked Priming Paradigm

Language researchers have used a wide variety of tasks to explore and understand the processes of skilled reading. Of the many tasks used to study the automatic processes involved in visual word recognition, the masked priming paradigm (see Figure 3) has proven to be one of the more useful tools available to researchers (see Kinoshita & Lupker, 2003, for a review). In the masked priming paradigm, a trial consists of the presentation of a forward mask ("####"), a prime word (typically presented for less than 60 ms), and a target word. Primes and targets are normally presented in different cases in order to minimize prime-target overlap at the perceptual level. In the masked priming paradigm, the prime is presented briefly and masked by both the forward mask and the target, making it virtually impossible for participants to be aware of its existence, much less its identity.

The most commonly employed experimental task under the masked priming situation is a lexical decision task. In this task, participants are asked to decide as quickly and as accurately as possible whether a presented string of letters is a word or not. Participants press a button to indicate their decision. For half of the trials, the targets are real words (requiring the participant to press the YES button); for the other half of the trials, the targets are nonwords (requiring the participant to press the NO button). This design eliminates response bias toward one type of response over the other.

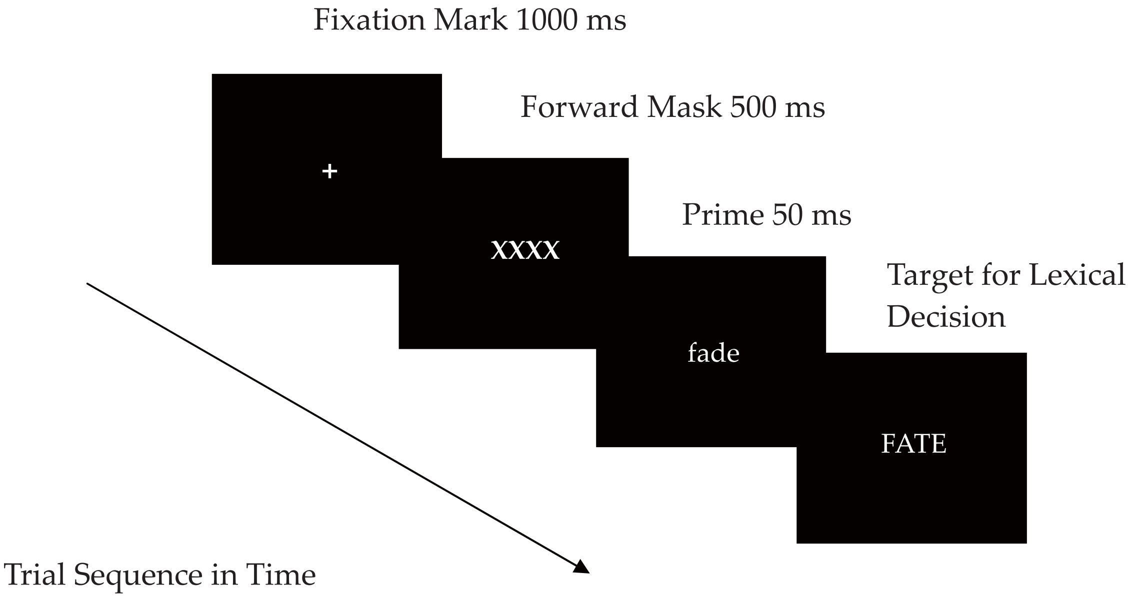

Figure 3. A Trial Sequence of the Masked Priming Paradigm.

Researchers test priming effects by comparing responses to target words (e.g., TIDE) that are preceded by critical primes (e.g., side) and control primes (e.g., rock). Primes are presented in a counterbalanced manner across participants, so that for each target, each participant receives only one type of prime. The assumption of the masked priming paradigm is that when a prime is presented, relevant lexical information (i.e., the prime's orthographic, phonological, lexical and semantic representations) is automatically activated. These pre-activated representations exert influences on the recognition of subsequent target word, especially when lexical representations of the prime and target words are in part or whole stored intertwiningly in the mental lexicon.Researchers manipulate the lexical relationship between primes and targets and assess the nature of lexical propertiesand their organization in the mental lexicon.

There are a number of advantages in the masked priming paradigm to investigate the nature of lexical representations in the mental lexicon. The most obvious advantage is that primes are not consciously processed by participants; therefore, their impact on target processing can be assessed without possible sources of confounds associated with conscious prime processing. There are two specific advantages to note. For one, masked primes safeguard against response strategies. With a clearly visible prime, participants would be able to intentionally generate possible related targets based on the previously presented prime-target pairs and, hence, a priming effect would be amplified if some targets are correctly generated by the primes. For example, Neely (1977) reported a significant priming effect even for unrelated pairs (e.g., building – robin), when participants were instructed to expect exemplars of a specific category (birds) when the prime was a different category (building). In the masked priming paradigm, however, it is virtually impossible to notice the prime-target relationships because the primes are invisible. Hence, this paradigm allows researchers to focus on automatic lexical processing and not expectancy effects.

Another benefit of unconscious primes is that the episodic memory trace of a prime would not be established. As a result, the relationship between the prime and the target cannot be evaluated and, hence, cannot cue the response (i.e., minimizing the influence of retrospective priming). Given that information about words is stored in a lexical memory system, a masked priming paradigm is especially suited for word recognition research; the data obtained with the paradigm represents a relatively pure lexical process with minimal influence from the episodic memory system (see Forster & Davis, 1984, and Kinoshita & Lupker, 2003, for detailed discussion of this issue).

Another major advantage of the masked priming paradigm is that the same stimuli are responded to in different experimental conditions. For example, responses to the same target word (e.g., FATE) are measured after being primed by an orthographically-similar word (e.g., *fade*) and an orthographically-unrelated word (e.g., *slim*). Unlike a single item presentation paradigm where performances to different sets of words are compared, the masked priming paradigm compares response latencies and accuracy to the same target. Because differences in the response latencies (and accuracy) to the same target are the basis of the orthographic priming effect, there are no concerns about uncontrolled stimulus differences across experimental conditions, unlike a single item presentation paradigm in which performances to different set of words have to be compared.

Inhibitory Masked Neighbor Priming Effect

The masked priming paradigm has been an especially important tool for studying the lexical competition principle incorporated in most localist, activation-based models of visual word recognition(Davis, 2003; McClelland & Rumelhart, 1981; Grainger & Jacobs, 1996). Results from the masked priming paradigm (Forster & Davis, 1984) provide some of the most convincing evidence for the lexical competition process embodied in the activation-based models.

Segui and Grainger (1990) were the first to use the masked priming paradigm to look for evidence of lexical competition predicted by the activation-based models. Their stimuli involved French (Experiment 2) and Dutch (Experiment 3). They assumed that presenting a word prime that was a neighbor of the target would pre-activate the prime's lexical unit and significantly increase the prime's ability to compete with the target. A word pair with a high-frequency neighbor prime and a low-frequency target (e.g., *blue*–*BLUR*) would create interference than a word pair with an unrelated prime and target (e.g., *care*–*BLUR*). A word pair with a low-frequency neighbor prime and a high-frequency target (e.g., *blur–BLUE*) would be expected to produce little interference since the prime would not be a strong competitor even when pre-activated. Consistent with these predictions, Segui and Grainger found that lexical decision latencies were significantly slower when low-frequency target words were primed by high-frequency neighbors than when they were primed by unrelated words. Response latencies were not significantly different when high-frequency target words were primed by low-frequency neighbors or unrelated words.

More recently, a number of studies have demonstrated that the neighborhood size of the prime and target also affects inhibition from neighbor primes (Davis & Lupker, 2006; Nakayama, Sears, & Lupker, 2008). For instance, Nakayama et al. (2008), found that the pattern of inhibitory neighbor priming effects for English stimuli was significantly different for neighbor prime-target pairs with many neighbors (M = 10) than for neighbor prime-target pairs with few neighbors (M = 2.7). When primes and targets had relatively few neighbors, only higher-frequency neighbor primes produced the inhibitory priming effect. Lower- frequency neighbors did not produce a significant inhibition effect. These results are consistent with the activation-based models of visual word recognition and previous masked priming studies including the original finding of Segui and Graigner (1990).

On the other hand, when primes and targets had many neighbors, both higher-frequency neighbors and lower-frequency neighbors produced interference equally. That is, higher-frequency targets primed by lower-frequency neighbors (e.g., side-TIDE) were inhibited as much as lower-frequency targets primed by higher-frequency neighbors (tide-SIDE).

Post-hoc analyses of Nakayama et al. (2008) showed that for higher-frequency targets primed by lower-frequency neighbors, the size of the inhibition effect increased linearly as the number of neighbors of the prime-target pairs increased. On the other hand, no such relationship was found for lower-frequency targets primed by higher-frequency neighbors. These results suggest that higher-frequency neighbor word itself is a powerful competitor to inhibit target processing, making the number of neighbors of the prime-target pairs is irrelevant. More importantly, these results also suggest that when words have many competitors (neighbors), the combined inhibition from lower frequency neighbors creates considerable competition even for higher-frequency targets.

Facilitory Masked Nonword Neighbor Priming Effect

Another important point is that should be noted is that if the neighbor prime is a nonword, lexical competition is substantially reduced, because a nonword does not have a lexical representation and, therefore, has little ability to produce competition. In this case, the expected outcome is facilitation rather than inhibition, which is consistent with the results of a number of previous studies (e.g., Andrews & Hersch, 2010; Davis & Lupker, 2006; Forster, Davis, Schoknecht, & Carter, 1987; Forster & Veres, 1998). The facilitation effects from nonwords are especially pronounced when prime-target pairs have a relatively small number of neighbors. For prime-target pairs that have many neighbors, on the other hand, target processing is typically neither facilitated nor inhibited by nonword neighbor primes (i.e., *density-constraint effect*, Forster, 1987; Forster et al., 1987).

The results from previous nonword neighbor priming studies suggest that some of the processes engaged by an orthographically-similar prime can facilitate target processing (see Davis, 2003, for a detailed discussion of how these facilitory and inhibitory processes interact at the lexical level). In addition to the facilitation at the lexical level, it is also possible that some facilitation may arise at the orthographic level (due to the repetition of the letters/characters themselves) and/or at the phonological level (e.g., Frost, 2003).

The existence of an inhibition effect from word neighbor primes, in contrast to a facilitation (or null) effect from nonword neighbor primes, therefore, documents the impact of lexical competition in a masked priming situation. This finding implies that the inhibitory effect is so strong that it surpasses facilitation effects that are also at work due to form similarities.

Present Study.

To this date, inhibitory neighbor priming effects have been reported in many languages, including Dutch (e.g., Brysbaert, Lange, & Van Wijnendaele, 2000; Drews

&Zwitserlood, 1995; De Moor & Brysbaert, 2000; Segui & Graigner, 1990), Spanish (Carreiras & Duñabeitia, 2009; Duñabeitia, Perea, & Carreiras, 2009), French (Segui & Graigner, 1990) and English (e.g., Davis & Lupker, 2006; Janack, Pasizzo, & Feldman, 2004; Nakayama, Sears, & Lupker, 2008). These inhibitory effects suggest that lexical competition plays an important role in the visual word recognition process of a number of languages. Note, however, that these studies used Indo-European languages with the Roman alphabet. To some extent, this situation stems from the fact that the original activation-based model, the interactive-activation model (McClelland & Rumelhart, 1981), was based on the English lexicon, and hence, incorporated letter units for Roman letters.

Therefore, what is not clear is whether lexical competition is a process specific to languages that employ the Roman alphabet or if lexical competition also applies to languages that use other scripts. Activation-based models involve concepts related to lexical units and lexical competition. If these concepts are not language (script) dependent, then inhibitory neighbor priming effects should also be observed for languages not based on Roman letters. The present research examined this question.

More specifically, the present research looked for evidence of an inhibitory neighbor priming effect for Japanese Katakana and Kanji words using the masked priming paradigm. In Chapter 2, the lexical competition assumption is tested with words in Katakana, a phonetic script. In Chapter 3, the lexical competition assumption is tested with words in Kanji, a logographic script.

Definition of Katakana and Kanji Orthographic Neighbors.The present research adapted the original definition of an orthographic neighbor proposed by Coltheart et al. (1977). An orthographic neighbor was defined as a word created by changing one character while maintaining the relative character position. A character, as opposed to a letter, was used as the orthographic unit. For example, Katakana words such as アース (“earth”), スイス(“Switzerland”), アイヌ(“Ainu”), ナイス(“nice”) were considered orthographic neighbors of アイス(“ice, ice cream, popcicle”). Similarly, Kanji words such as 国際 (“international”), 交際 (“companionship”), and 間際 (”on short notice”), and also words such as 会議 (“conference”), 会釈 (“nodding/greeting”), and 会話 (“conversation”) were considered orthographic neighbors.

General Predictions of the Present Study. The general prediction of the present study was straightforward. If lexical competition plays an important role when reading Japanese words, much like the case with words written in alphabetic languages, then response times and accuracy of lexical decision should be significantly impaired for targets primed by orthographic neighbors than for targets primed by unrelated words. In addition, activation-based models of visual word recognition (Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981) predict that the inhibition effect is due to lexical competition between activated word units. If lexical competition accounts for the inhibition effect, then no such effect should be observed when the same targets are primed by nonword neighbors.

Of course, the lexical processing of Katakana and Kanji words may be somewhat different from each other. Thus, even if the lexical competition assumption is applicable to both of these words, the sizes of neighbor priming effect may be somewhat different depending on the type of the words. In fact, as will become apparent in the following chapters,the precise predictions were different for the Katakana and Kanji words, because they have different morphological structures andthus, somewhat different processes are expected when reading these words.

Nevertheless, if lexical competition is a phenomenon specific to words in alphabetic languages, then no evidence of an inhibitory neighbor priming effect should be found for either type of words (i.e., Katakana and Kanji words). In addition, if PDP-type models (Seidenberg & McClelland, 1989; Plaut et al., 1996) better explain the visual word recognition process of Katakana and Kanji words, then neighbor primes should significantly facilitate target processing relative to unrelated primes because neighbor prime-target pairs have greater featural overlap (they are orthographically and phonologicallysimilar) than unrelated prime-target pairs. PDP-type models would also predict that word neighbor primes and nonword neighbor primes would produce an equivalent amount of facilitation, because, as noted earlier, these models do not assume local representations at the lexical level, and therefore, do not expect lexical competitionamong lexical-level representations. Thus, the lexicality of the primes should not change the pattern of the neighbor priming effects, as word and nonword neighbors having equivalent orthographic and phonological featural overlap with their targets.

Chapter 2: Lexical Competition in a Non-Roman, Syllabic Script: An Inhibitory Neighbor Priming Effect in Japanese Katakana

This chapter is based on

Nakayama, M., Sears, C. R., & Lupker, S. R. (2011). Lexical Competition in a Non-Roman, Syllabic Script: An Inhibitory Neighbor Priming Effect in Japanese Katakana. *Language and Cognitive Processes, 26*, 1136-1160.

Overview

In this section, I will present the results of two experiments that tested neighbor priming effects with Japanese Katakana words. To my knowledge, these experiments were among the first to test the masked orthographic neighbor priming effect using Katakana words. Experiment 1 consisted of two subsets of studies; these studies compared the effect of prime lexicality,with word neighbor primes and nonword neighbor primes. Experiment 2 was the replication of Experiment 1 with a different set of stimuli and a different group of participants. In Experiment 2, the effect of prime lexicality was tested in a within-subject design, rather than with two groups of participants.

Characteristics of Katakana Words

Katakana is normally used to transcribe words that originated in foreign languages, although it is also used for animal and plant names at times. Similar to Roman letters, Katakana characters themselves do not carry any meaning. Like the Roman alphabet, Katakana uses a relatively limited set of orthographic units (characters). One must identifythe relative letter/character positions within a word to correctly decipher the word. Unlike Roman letters, however, each Katakana character represents a *mora*. *Morae* are rhythmic units with a constant duration, most of which correspond to a syllable, consisting of either a single vowel (e.g., ア/a/, イ/i/, ウ/u/, エ/e/, and オ/o/) or a combination of a consonant and a vowel (e.g., カ/ka/, キ/ki/, マ/ma/,

ミ /mi/). As such, Katakana characters are a syllabic script. This is different from Roman letters, as they are a phonemic script, where a phoneme refers to the smallest unit of speech sound of a word. Another (yet obvious) difference between Katakana characters and Roman letters is that their orthographies share virtually no featural similarities with one another. Therefore, while words in Katakana and alphabetic letters share some aspects (i.e., phonemes), they have quite different orthographic forms (e.g., "マスク, /ma.su.ku/" and "mask, /mæsk/").

A Test of Lexical Competition Assumption with Katakana Neighbors

As reviewed in Chapter 1, previous masked priming studies have shown that masked neighbor primes significantly inhibit target processing relative to unrelated primes (e.g., Brysbaert et al., 2000; Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Duñabeitia, et al., 2009; Janack et al., 2004; Nakayama, et al., 2008; Segui & Grainger, 1990). Such significant inhibition effects are taken as evidence that lexical competition exists in the visual word recognition of alphabetic languages, and that the masked priming paradigm is a sensitive tool to capture such competition.

The presence of inhibitory neighbor priming effects suggests does not only support the idea that the lexical competition is an important process involved in the reading of visually presented words, but it also has an important theoretical implication in the models of visual word recognition. That is, the presence of inhibitory neighbor priming effects support the notion that each word has a unique local representation at the lexical level, an assumption that is commonly held by activation-based models of visual word recognition (Davis, 2003; McClelland & Rumelhart, 1981; Grainger & Jacobs, 1996). Such a notion is not currently incorporated in another class of models such as PDP-type models (Seidenberg & McClelland, 1989; Plaut et al., 1996). As noted earlier, according to PDP-type models, there are no local units corresponding to words. According to this type of models, competition cannot occur because there is no lexical representation for a prime to pre-activate and, hence, there would be no competition among activated lexical representations. Thus, a straightforward prediction according to PDP-type models is that, regardless of prime lexicality, neighbor primes should facilitate target processing due to their featural overlap (i.e., orthographic and phonological overlap).

To date, no study has tested the lexical competition assumption in a language that does not employ Roman scripts. The present research examined inhibitory neighbor priming effects using Japanese Katakana words to see if lexical competition applies to other languages. In this study, Katakana targets were primed by either orthographic neighbors of targets or by unrelated primes with matched lexical properties (i.e., script type, lexicality, word lengths, word frequency, and number of neighbors, etc). As noted in Chapter 1, to operationally define the Katakana orthographic neighbors, the definition of orthographic neighbors by Coltheart et al., (1977) was adapted. Katakana orthographic neighbors were created by treating a character as functionally equivalent to a letter in alphabetic languages. To test the lexical competition assumption with Katakana words, two important variables were tested: 1) relative word frequencies of neighbor prime-target pairs, and 2) the lexicality of the primes. In addition, all of the stimuli selected for the experiments had a relatively large number of neighbors.

As noted, no previous study has examined the lexical competition assumption using words in non-alphabetic languages. Therefore, it was not at all clear whether the inhibitory neighbor priming effects would be observed with Katakana neighbor primes. A recent study by Perea and Pérez (2009), however, found some evidence of similarities in the lexical processing of Katakana and English words, despite the apparent differences between Katakana characters and alphabetic letters.

Using a masked priming paradigm with a 50 ms prime duration, Perea and Pérez (2009) showed that Katakana transposed-character nonword primes significantly facilitated lexical decision responses to targets (a.ri.me.ka–a.me.ri.ka アリメカ–アメリカ) in comparison to control primes where the transposed characters were replaced (a.ka.ho.ka–a.me.ri.ka アカホカ–アメリカ). This result is consistent with the results of English studies on transposed-letter priming (e.g., the transposed prime *jugde* primes the target *judge* in comparison to the replacement-letter prime *judpe*;for a review, see Perea & Lupker, 2003).

The implication of the results of Perea and Pérez (2009) is that, despite their different orthographies and despite the fact that the characters/letters in the two languages represent different linguistic components (i.e., phonemes vs. morae), similar lexical processes may underlie the reading of Katakana and English words. If this is true, then lexical competition may also occur in the processing of Katakana words.

Experiment 1

Experiment 1 was the first attempt to examine the inhibitory neighbor priming effects for Katakana words. This experiment consisted of two subsets of experiments: Experiment 1A and 1B. In Experiment 1A, low- and high-frequency Katakana targets were primed by lower-frequency and higher-frequency neighbors of these targets. An inhibitory neighbor priming effect from higher-frequency neighbor primes would suggest that lexical competition also plays a role in the processing of Katakana words. Katakana prime-target pairs had many neighbors, as was the case in the previous masked priming study in English (Nakayama, et al., 2008). In Nakayama et al. (in their Experiments 1 and 2), significant inhibition from neighbor primes was found irrespective of relative frequency of the prime-target pairs. A finding consistent with the results of Nakayama et al. (i.e., a significant neighbor priming effect for lower-frequency targets primed by higher-frequency neighbors and also for higher-frequency targets primed by lower-frequency neighbors) would further support the idea that the assumption of activation-based models is not limited to alphabetic languages but applicable to non-alphabetic Japanese Katakana words.

In Experiment 1B, the same set of Katakana targets were primed by nonword neighbor primes and by orthographically-unrelated nonword primes. Experiment 1B (nonword primes) helped determine if inhibition effects from word neighbor primes were due to lexical competition, and not other factors associated with form similarities of prime-target pairs. If any observed inhibition effects were due to lexical competition, then nonword primes would not significantly inhibit target processing. Rather, nonword neighbors would produce either null or weak facilitation as seen in previous studies using alphabetic languages (e.g., Davis & Lupker, 2006; Forster, 1987; Forster, Davis, Schoknecht, & Carter, 1987; Forster & Veres, 1998; Perea & Rosa, 2000).

In contrast, according to PDP-type models, neighbor primes should facilitate lexical decision responses to targets relative to unrelated primes because the neighbor prime-target pairs share more featural similarities. In addition, because these models do not assume local representations at the lexical level, the priming effect size should be comparable regardless of the lexicality of the primes.

Method

Participants.Participants were 117 undergraduate students from Waseda University (Tokyo, Japan). Fifty-eight of the participants were shown targets primed by words (Experiment 1A) and 59 of the participants were shown targets primed by nonwords (Experiment 1B). All participants were native speakers of Japanese with normal or corrected-to-normal vision.

Stimuli. The stimuli for Experiment 1A were Katakana words of two to four characters in length. All of these words had many orthographic neighbors (with a mean of 28.8 neighbors; the number of orthographic neighbors was calculated using the NTT database, Amano & Kondo, 2000). As noted, orthographic neighbors were defined in the standard fashion (i.e., Coltheart et al., 1977), as words that are created by changing one Katakana character while holding the other characters constant. For example, レベル (re.be.ru, level) and ノベル (no.be.ru, novel) were considered Katakana orthographic neighbors, as were センター (se.N.ta.R, center) and セーター (se.R.ta.R, sweater). Note that because Katakana corresponds to a mora, the phonologies of orthographic neighbors typically differ by one mora (one or two phonemes).

Forty pairs of orthographic neighbors were selected as the critical stimuli (the descriptive statistics for these stimuli are shown in Table 1). For each pair, each neighbor served as either a prime or a target depending on the condition the pair was assigned to. The two stimuli in a pair had the same number of characters. One member of the neighbor pair was much higher in normative frequency (*M* = 61.7) than the other (*M* = 1.1).[1] The neighbor pairs were divided into four groups that had similar mean word frequencies and word lengths.

Table 1

Mean Normative Frequency (Per Million Occurrences) and Number of Neighbors of Stimuli Used in Experiment 1A

Stimulus characteristic	Neighbor prime	Unrelated prime	Target
	High frequency prime – low frequency target		
	センター *(se.N.ta.R, center)*	*トラック* *(to.ra.Q.ku, truck)*	*セーター* *(se.R.ta.R, sweater)*
Normative frequency	61.7	61.7	1.1
Number of neighbors	28.4	28.4	29.1
	Low frequency prime – high frequency target		
	セーター *(se.R.ta.R, sweater)*	*トラップ* *(to.ra.Q.pu, trap)*	*センター* *(se.N.ta.R, center)*
Normative frequency	1.1	1.1	61.7
Number of neighbors	29.1	29.1	28.4
	High-frequency prime – nonword target		
	モデル *(mo.de.ru, model)*	*ラジオ* *(ra.zi.o, radio)*	*カデル* *(ka.de.ru)*
Normative frequency	25.2	25.2	-
Number of neighbors	25.3	25.3	20.3
	Low-frequency prime – nonword target		
	オーダー *(o.R.da.R, order)*	*アルペン* *(a.ru.pe.N, alpine)*	*イーダー* *(i.R.da.R)*
Normative frequency	0.8	0.8	-
Number of neighbors	27.3	27.3	23.8

Two groups were used to create the orthographically-related conditions: for one group, the high-frequency member of the pair was the prime and the low-frequency member of the pair was the target; for the other group, the prime-target pairings were reversed. Unrelated prime-target pairs were created in the other two groups by re-pairing primes and targets, such that the unrelated primes did not share any characters with their targets. Unrelated primes had the same number of characters as their targets. For each neighbor pair, only one member of the pair was presented to a participant. This was accomplished by creating four counterbalanced lists. Four conditions of prime-target pairs in Experiment 1A are illustrated as below: 1) high-frequency neighbor prime – low-frequency target (e.g., センター–セーター), 2) high-frequency unrelated prime – low-frequency target (e.g. トラック–セーター), 3) low-frequency neighbor prime – high-frequency target (e.g., セーター–センター), and 4) low-frequency unrelated prime – high-frequency target (e.g., トラップ –センター).

Forty nonword targets of two to four characters in length and with many neighbors (*M* = 22.1) were created for the lexical decision task. Each nonword was paired with an orthographic neighbor having a large neighborhood (*M* = 26.3). Twenty nonwords were paired with high-frequency neighbors (*M* = 25.2) and the other 20 were paired with low-frequency neighbors (*M* = 0.8). To create the priming conditions for the nonwords, the 20 high-frequency neighbor prime–nonword target pairs were divided into two groups (of size 10) of similar word frequencies and neighborhood size. The 20 low-frequency neighbor prime–nonword target pairs were divided into two groups (of size 10) in a similar fashion. Unrelated prime–nonword target pairs were created by re-pairing the primes and targets such that the unrelated primes did not share any characters with their targets. Unrelated primes had the same character lengths as their targets. There were two counterbalancing lists for nonword targets. The word stimuli used in Experiment 1A are listed in Appendix A.

For Experiment 1B, Katakana targets were primed by nonword neighbors or by unrelated nonwords. The same prime-target pairs used in Experiment 1A were used to create stimulus pairs in Experiment 1B, with the exception of four pairs that were replaced by different items because of high error rates in Experiment 1A (greater than 60% for the prime or the target); these pairs were replaced with pairs with similar lexical characteristics.[2]

The word neighbor primes in these pairs were replaced by nonword neighbor primes (e.g., the pair "セルター(se.ru.ta.R) – セーター(se.R.ta.R, sweater)" was created changing the pair, "センター (se.N.ta.R, center) – セーター(se.R.ta.R, sweater)" pair). The nonword neighbor primes differed from the targets at one character position, and had the same character lengths and a similar number of neighbors as the targets (*M* = 25.1). The descriptive statistics for the stimuli used in Experiment 1B are shown in Table 2.

Table 2

Mean Normative Frequency (Per Million Occurrences) and Number of Neighbors of Stimuli Used in Experiment 1B

Stimulus characteristic	Neighbor prime	Unrelated prime	Target
	Nonword prime – low frequency target		
	セルター	*トラッコ*	*セーター*
	(se.ru.ta.R)	*(to.ra.Q.ko)*	*(se.R.ta.R, sweater)*
Normative frequency	—	—	1.3
Number of neighbors	25.1	25.1	29.5
	Nonword prime – high frequency target		
	セルター	*トラッコ*	*センター*
	(se.ru.ta.R)	*(to.ra.Q.ko)*	*(se.N.ta.R, center)*
Normative frequency	—	—	60.4
Number of neighbors	25.1	25.1	28.7
	Nonword prime – nonword target		
	リデル	*ラーオ*	*カデル*
	(ri.de.ru)	*(ra.R.o)*	*(ka.de.ru)*
Normative frequency	—	—	—
Number of neighbors	23.3	23.3	22.1

As in Experiment 1A, the neighbor pairs were divided into four groups. Two groups of the pairs had high-frequency targets; two groups had low-frequency targets. Mean word frequencies and word lengths of the targets were matched across the two high- and two low-frequency target groups. Unrelated prime-target pairs were created by re-pairing the primes and targets, such that the unrelated primes did not share any characters with their targets. Unrelated primes had the same number of characters as their targets. There were four counterbalanced lists; participants were randomly assigned to one of the four groups. Four conditions of prime-target pairs in Experiment 1B are illustrated as below: 1) nonword neighbor prime – low-frequency target (e.g.,セルター – セーター), 2) nonword unrelated prime – low-frequency target (e.g.,トラッコ – セーター), 3) nonword neighbor prime – high-frequency target (e.g.,セルター – センター), and 4) nonword unrelated prime – high-frequency target (e.g.,トラッコ – センター).

The nonword targets used in Experiment 1B were the same as those used in Experiment 1A. Forty nonword neighbors were created to prime these targets. The nonword neighbor primes had the same character lengths and a similar number of neighbors ($M = 23.3$) as the targets. Prime frequency was not manipulated since all of the nonword targets were primed by nonwords (either by a neighbor or an unrelated nonword). To create the priming conditions for the nonwords, the 40 neighbor pairs were divided into two groups (of size 20) of similar neighborhood size. Unrelated prime–nonword target pairs were created by re-pairing primes and targets, such that the unrelated primes did not share any characters with their targets. Unrelated primes had the same character lengths as their targets. There were two counterbalancing lists for nonword targets. The word stimuli used in Experiment 1B are listed in Appendix B.

Apparatus and procedure.Each participant was tested individually. The experiment was programmed using the DMDX software package (Forster & Forster, 2003) and stimuli were presented on 21-inch video display driven by a desktop computer. Primes were presented in a smaller font than targets in order to minimize the physical overlap between primes and targets. Although, physical overlap is minimized for alphabetic languages by using different letter cases for primes and targets (e.g., a lowercase prime and an uppercase target), this case manipulation is not possible for Katakana script.

Each trial began with the presentation of a fixation marker (+) in the center of display for 500 ms. A visual mask (####) then appeared in the center of the display for 500 ms, followed by the prime. The prime was presented for 50 ms and was immediately replaced by the target. Participants were instructed to quickly and accurately indicate whether the target was a word or not by pressing one of two buttons (labeled *word* and *nonword*) on a response box placed in front of them. The existence of the prime was not mentioned. The target remained on the screen until a response was made. Each participant completed 16 practice trials prior to the experimental trials to familiarize themselves with the lexical decision task (these practice stimuli were not used in the experimental trials). The order in which the experimental trials were presented was randomized separately for each participant.

Results

Table 3 shows the mean response latencies and errors for targets primed by words (Experiment 1A). Table 4 shows the mean response latencies and errors for targets primed by nonwords (Experiment 1B).

Targets Primed by Words (Experiment 1A).Data from participants with overall error rates greater than 20% were excluded from all the analyses ($n = 2$).[3] Response latencies less than 300 ms or greater than 1,400 ms were treated as outliers and were removed from all the analyses (0.2% of responses latencies for word targets and 0.4% for nonword targets). For the word data, response latencies of correct responses and error rates were submitted to a 2 (Prime Type: neighbor prime, unrelated prime) x 2 (Target Frequency: high-frequency, low-frequency) factorial analysis of variance (ANOVA). In the subject analysis (F_s), both factors were within-subject factors. In the item analysis (F_i), Prime Type was a within-item factor and Target Frequency was a between-item factor.

Responses were slower and more error prone when targets were primed by orthographic neighbors (591 ms, 14.7%) than when they were primed by unrelated words (578 ms, 10.0%). There was a significant effect of Target Frequency in the response latency analysis, $F_s(1, 55) = 94.82$, $p < .001$, $MSE = 2{,}284.5$, partial $\eta^2 = .63$;$F_i(1, 70) = 38.29$,

$p < .001$, $MSE = 5{,}289.9$, partial $\eta^2 = .35$, as well as in the error analysis, $F_s(1, 55) = 144.35$, $p < .001$, $MSE = 99.9$, partial $\eta^2 = .72$; $F_i(1, 70) = 26.42$, $p < .001$, $MSE = 343.3$, partial $\eta^2 = .27$. Responses to high-frequency targets were faster than responses to low-frequency targets (553 ms vs. 616 ms), and fewer errors were made to high-frequency targets (4.4% vs. 20.4%). There was no interaction between Prime Type and Target Frequency in the analysis of response latencies (both $Fs < 1$), with similar inhibition effects from high-frequency neighbor primes (17 ms) and low-frequency neighbor primes (10 ms).

For error rates, the interaction between Prime Type and Target Frequency was significant in the item analysis, $F_i(1, 70) = 4.02$, $p < .05$, $MSE = 79.3$, partial $\eta^2 = .05$, although not in the subject analysis, $F_s(1, 55) = 2.79$, $p = .10$, $MSE = 159.2$, partial $\eta^2 = .05$. Follow-up analyses of the item means revealed that the 7.5% inhibition effect from high-frequency neighbor primes was statistically significant, $t_i(35) = 2.88$, $p < .01$, $SEM = 2.7$, whereas the 1.9% effect from low-frequency neighbor primes was not, $t_i(35) = 1.43$, $p > .10$, $SEM = 1.3$.

For the nonword targets primed by words, the ANOVA factors were Prime Type (neighbor prime, unrelated prime) and Prime Frequency (high-frequency prime, low-frequency prime). Both factors were within-subject factors in the subject analysis. In the item analysis, Prime Type was a within-item factor and Prime Frequency was a between-item factor. The only significant result in the analysis of response latencies was

Table 3

Experiment 1A: Mean Lexical Decision Latencies (RT, in ms) and Percentage Errors for Word and Nonword Targets Primed by Words

Word targets

Prime type	Prime-target frequency			
	High-low		Low-high	
	RT	Errors	RT	Errors
Neighbor	624	24.1	558	5.3
Unrelated	607	16.6	548	3.4
Difference	-17	-7.5	-10	-1.9

Nonword targets

	Prime frequency			
	High		Low	
	RT	Errors	RT	Errors
Neighbor	622	5.4	626	6.8
Unrelated	630	5.0	638	6.8
Difference	8	-0.4	12	0

Table 4

Experiment 1B: Mean Lexical Decision Latencies (RT, in ms) and Percentage Errors for Word and Nonword Targets Primed by Nonwords

Word targets

Prime type	Target frequency			
	Low		High	
	RT	Errors	RT	Errors
Neighbor	594	15.7	547	5.5
Unrelated	600	13.6	547	3.2
Difference	6	-2.1	0	-2.3

Nonword targets

	RT	Errors
Neighbor	614	5.4
Unrelated	631	5.8
Difference	17	0.4

the significant effect of Prime Type in the subject analysis, $F_s(1, 55) = 4.54$, $p < .05$, $MSE = 1{,}275.6$, partial $\eta^2 = .08$; $F_i(1, 38) = 3.72$, $p = .06$, $MSE = 616.4$, partial $\eta^2 = .09$. Targets primed by neighbors were responded to faster (624 ms) than targets primed by unrelated words (634 ms).

Targets Primed by Nonwords (Experiment 1B). To be consistent with Experiment 1A, data from participants with overall error rates greater than 20% were excluded from all analyses ($n = 3$) and response latencies less than 300 ms or greater than 1,400 ms were treated as outliers (0.1% of responses latencies for word targets and 0.4% for nonword targets).[4]

For word targets, the data were analyzed in the same manner as in Experiment 1A. Unlike the situation in Experiment 1A, the effect of Prime Type was not significant in the response latency analysis (both *F*s< 1). As can be seen in Table 4, responses to words primed by nonword neighbors were not any slower than responses to words primed by unrelated words. In the error analysis, the effect of Prime Type was marginally significant, $F_s(1, 55) = 3.31$, $p = .07$, $MSE = 82.7$, partial $\eta^2 = .06$;$F_i(1, 76) = 2.94$, $p = .09$, partial $\eta^2 = .04$, with slightly higher error rates for targets primed by neighbors (10.6%) than for targets primed by unrelated primes (8.4%). There was a significant effect of Target Frequency in the response latency analysis, $F_s(1, 55) = 87.04$, $p < .001$, $MSE = 1{,}585.1$, partial $\eta^2 = .61$;$F_i(1, 76) = 23.87$, $p < .001$, $MSE = 5{,}824.3$, partial $\eta^2 = .24$, as well as in the error analysis, $F_s(1, 55) = 70.64$, $p < .001$, $MSE = 84.2$, partial $\eta^2 = .56$; $F_i(1, 76) = 19.48$,

$p < .001$, $MSE = 219.6$, partial $\eta^2 = .20$. Responses to high-frequency targets were faster than responses to low-frequency targets (547 ms vs. 597 ms) and fewer errors were made to high-frequency targets (4.4% vs. 14.7%). There was no interaction between Prime Type and Target Frequency for either response latencies (both *F*s< 1) or errors (both *F*s< 1).

For nonword targets, the data were analyzed with single factor ANOVAs with two levels (Prime Type: neighbor vs. unrelated). The effect of Prime Type was significant in the response latency analysis, $F_s(1, 55) = 12.98$, $p < .001$, $MSE = 668.1$, partial $\eta^2 = .19$;$F_i(1, 39) = 8.72$, $p < .01$, $MSE = 763.9$, partial $\eta^2 = .18$. Targets were rejected as nonwords significantly faster when preceded by a nonword neighbor (614 ms) than an unrelated nonword (631 ms). In the error analysis the effect of prime type was not significant (both *F*s< 1).

Combined Analyses of Experiments 1A and 1B.The word data from the two experiments were analyzed together to confirm that the priming effects differed as a function of Prime Type (word or nonword), given the different pattern of results from word primes (an inhibitory priming effect) and nonword primes (a null priming effect). The analyses were based on the items that were analyzed both in Experiment 1A and Experiment 1B (34 low-frequency items and 36 high–frequency items). In the response latency analysis, the two-way interaction between Prime Lexicality (word prime, nonword prime) and Prime Type (neighbor prime, unrelated prime) was significant, F_s(1,

110) = 4.24, $p < .05$, $MSE = 2{,}100.5$, partial $\eta^2 = .04$;$F_i(1, 68) = 3.95$, $p = .05$, $MSE = 1114.4$, partial $\eta^2 = .06$. This interaction confirmed that word and nonword primes produced different priming effects, namely, a 14 ms inhibitory priming effect for word neighbor primes and a 3 ms facilitory priming effect for nonword neighbor primes (averaged across high- and low-frequency targets). For error rates there were no significant interactions (all *p*s > .10).

Discussion

The contrast between the results of Experiments 1A and 1B suggests that the inhibitory neighbor priming effect reported in Indo-European languages also exists in Japanese Katakana. Lexical decision latencies to word targets were significantly slower and more error prone when targets were primed by orthographic neighbors than when they were primed by unrelated words, whereas this was not true when the same targets were primed by orthographic neighbors that were nonwords. This outcome makes sense if the inhibitory neighbor priming effect from word primes is due to lexical competition.

Another result to note was that responses to targets were inhibited by neighbor primes regardless of relative prime-target frequency. Recall that Katakana prime-target pairs used in this experiment had many neighbors (*M* = around 25). This outcome is consistent with recent studies that have used English stimuli with many neighbors (Davis & Lupker, 2006; Nakayama et al., 2008) and Spanish stimuli with many neighbors (Carreiras & Duñabeitia, 2009). Nakayama et al. found that the inhibition effect interacts with neighborhood size and the prime–target frequency relationship: when words have few neighbors (e.g., *M* = 3.5), there is inhibition only from higher-frequency neighbor primes, whereas when words have many neighbors (e.g., *M* = 10), there is inhibition from both higher- and lower-frequency neighbor primes. The equivalent inhibition effects observed for high-frequency targets primed by low-frequency neighbors and for low-frequency targets primed by high-frequency neighors further supports the idea that lexical competition exists when reading Katakana words, much like the case with English words.

Experiment 2

The contrasting results of Experiments 1A and 1B nicely demonstrate that inhibitory neighbor priming effectsreflect lexical-level processes. However, one potential confound was that prime lexicality was tested with two groups of participants. Therefore, the results observed in Experiments 1A (word neighbor primes) and 1B (nonword neighbor primes) could have been due to idiosyncratic differences between the two groups of participants rather thanprime lexicality per se. Experiment 2 was conducted to test the reliability of the results observed in Experiment 1. In Experiment 2, prime lexicality was manipulated within-subjects to produce a more stringent test of the impact of prime lexicality on neighbor priming (see Davis & Lupker, 2006). Also, in Experiment 2, an inhibitory neighbor priming effect in Katakana was tested with a new set of targets and primes, and with a new group of participants. Because low-frequency targets produced the largest inhibition effect in Experiment 1A and the most evidence of facilitation in Experiment 1B, we used only low-frequency targets in Experiment 2.

Method

Participants.The participants were 36 undergraduate students from Waseda University, none of whom participated in Experiment 1. All participants were native speakers of Japanese.

Stimuli.The descriptive statistics for these stimuli are shown in Table 5. The stimuli were Katakana words of three to five characters in length. The average number of neighbors for these stimuli was 6.7 (Amano & Kondo, 2000). Sixty low-frequency Katakana words (*M* = 1.6 occurrences per million) were selected as targets. Each target (e.g., サーカス, sa.a.ka.su, circus) was primed by either a high-frequency word neighbor (*M* = 40.3 occurrences per million; e.g., サービス, sa.R.bi.su, service) or a nonword orthographic neighbor (e.g., サーロス, sa.R.ro.su). The targets had the same number of characters as their primes. As was done in Experiment 1, unrelated prime-target pairs were created by re-pairing the neighbor pairs. Unrelated primes and targets did not have an overlapping character at the same character position and were always the same length. There were four prime-target conditions: 1) high-frequency neighbor prime – low-frequency target (e.g., サービス – サーカス), 2) high-frequency unrelated prime – low-frequency target (e.g., イメージ – サーカス), 3) nonword neighbor prime – low-frequency target (e.g., サーロス – サーカス), and 4) nonword unrelated prime –

Table 5

Mean Normative Frequency (Per Million Occurrences) and Number of Neighbors of Stimuli Used in Experiment 2

	Word		Nonword		
Stimulus characteristic	Neighbor prime	Unrelated prime	Neighbor prime	Unrelated prime	Target
			Word and nonword prime – word target		
	サービス	*イメージ*	*サーロス*	*ルメージ*	*サーカス*
	(sa.a.bi.su, service)	*(i.me.e.ji, image)*	*(sa.a.ro.su)*	*(ru.me.e.ji)*	*(sa.a.ka.su, circus)*
Normative frequency	40.3	40.3	—	—	1.6
Number of neighbors	6.7	6.7	6.5	6.5	6.7
			Word and nonword prime – nonword target		
	パターン	*チャンス*	*マターン*	*チャンホ*	*シターン*
	(pa.ta.a.n, pattern)	*(cha.n.su, chance)*	*(ma.ta.a.n)*	*(cha.n.ho)*	*(shi.ta.a.n)*
Normative frequency	35.0	35.0	—	—	—
Number of neighbors	4.6	4.6	4.8	4.8	5.2

low-frequency target (e.g., ルメージ – サーカス). The word stimuli are listed in Appendix C.

For each target, only one type of prime was presented to a participant. Thus, there were four counterbalancing lists, with 15 items per condition. The assignment of groups to conditions was counterbalanced across participants.Sixty nonword targets of three to six characters in length were created. The mean number of neighbors for the nonwords was 5.2. Each nonword (e.g., シターン) was paired with either a word neighbor (*M* = 35.0 occurrences per million, e.g., パターン) or a nonword neighbor (e.g., マターン). Unrelated prime–nonword target pairs were created by repairing the neighbor pairs. There were four counterbalancing lists for nonword targets.

Apparatus and procedure.These were the same as those used in Experiment 1.

Results

Table 6 shows the mean response latencies and errors for targets primed by words and nonwords. To be consistent with Experiment 1, response latencies less than 300 ms or greater than 1,400 ms were treated as outliers and were removed from all analysis (0.1% of responses latencies for word targets and 0.3% for nonword targets).[5] Response latencies of correct responses and error rates were submitted to 2 (Prime Lexicality: word prime, nonword prime) x 2 (Prime Type: neighbor prime, unrelated prime) factorial ANOVAs. In the subject (F_s) and item analysis (F_i) these factors were within-subject and within-item factors, respectively.

The critical statistical test was the interaction between Prime Lexicality and Prime Type. This interaction was significant in the response latency analysis by subjects and by items, $F_s(1, 35) = 12.72$, $p < .01$, $MSE = 853.9$, partial $\eta^2 = .27$; $F_i(1, 56) = 11.36$, $p < .01$, $MSE = 2{,}148.9$, partial $\eta^2 = .17$. As can be seen in Table 6, there was a 28 ms inhibitory priming effect for word neighbor primes and a small (6 ms) facilitory priming effect for nonword neighbor primes, replicating the pattern of priming effects observed in Experiment 1.

The only other significant effect was the main effect of Prime Type in the error analysis, $F_s(1, 35) = 46.24$, $p < .001$, $MSE = 55.4$, partial $\eta^2 = .57$; $F_i(1, 56) = 36.65$, $p < .001$, $MSE = 109.3$, partial $\eta^2 = .40$, and, by items in the response latency analysis, $F_s(1, 35) = 2.81$, $p = .10$, $MSE = 1{,}519.9$, partial $\eta^2 = .07$; $F_i(1, 56) = 4.41$, $p < .05$, $MSE = 3{,}039.9$, partial $\eta^2 = .07$. Responses were slower and more error prone when targets were primed by orthographic neighbors (594 ms, 13.6%) than when they were primed by unrelated words (583 ms, 5.2%). That is, although for response latencies the effect of Prime Type was qualified by the Prime Lexicality x Prime Type interaction, for error rates it was not. As can be seen in Table 6, for word targets, both word and nonword related primes led to higher error rates than did unrelated primes.

For nonword targets, the effect of Prime Type was significant in the response latency analysis, $F_s(1, 35) = 24.78$, $p < .001$, $MSE = 1{,}281.7$, partial $\eta^2 = .42$;$F_i(1, 59) = 25.69$, $p < .001$, $MSE = 2{,}384.1$, partial $\eta^2 = .30$, with faster responses to nonwords primed by neighbors (621 ms) than to nonwords primed by unrelated primes (651 ms). The effect of

Table 6

Experiment 2: Mean Lexical Decision Latencies (RT, in ms) and Percentage Errors for Word Targets and Nonword Targets Primed by Words and by Nonwords

Word targets				
Prime type	Word primes		Nonword primes	
	RT	Errors	RT	Errors
Neighbor	603	14.4	584	12.7
Unrelated	575	4.7	590	5.6
Difference	-28	-9.7	6	-7.1
Nonword targets				
Neighbor	629	4.8	613	4.4
Unrelated	652	5.7	649	5.4
Difference	23	0.9	36	1.0

Prime Lexicality was marginally significant only in the subject analysis, $F_s(1, 35) = 3.71$, $p = .06$, $MSE = 980.0$, partial $\eta^2 = .10$; $F_i(1, 59) = 2.71$, $p = .11$, $MSE = 1{,}572.8$, partial $\eta^2 = .04$. No other effects were significant (all ps > .10).

Discussion

The results of Experiment 2 clearly showed that word neighbor primes produced significant inhibitory priming, whereas nonword neighbor primes produced, at most, a small facilitory priming effect. As noted, the small facilitory priming effect from nonword Katakana primes for low-frequency word targets with many neighbors is consistent with the results reported in previous priming studies using alphabetic languages (e.g., Forster et al., 1987; Perea & Rosa, 2000).

One other result of interest is the inhibition effect on error rates when nonword neighbors primed words. Recall that in Experiment 1B there was also a small inhibition effect on error rates when nonword neighbors primed words. These inhibitory effects from nonword neighbors are not unique to Katakana words because other investigators have reported the same effect when nonword neighbors primed English words with many neighbors (Forster, 1987; Forster, et al., 1987). According to the simulations reported by Davis (2003), the inhibitory effect is due to the fact that nonword neighbors have some limited ability to inhibit word targets, albeit indirectly, by partially activating the lexical representations of the target word’s neighbors (see Davis, 2003, for a detailed account of this process in activation-based models). As activation-based models predict, however, this inhibitory effect from nonword neighbor primes is always much weaker than the effect from word neighbors and is seldom observed in response latency data because the inhibition created is swamped by the facilitory effects produced by lexical preactivation.[6,7]

General Discussion: Katakana Neighbors

The purpose of the present research was to determine whether the inhibitory neighbor priming effect reported when using Indo-European languages such as English, French, Dutch, and Spanish (e.g., Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Duñabeitia et al., 2009; Nakayama et al., 2008; Segui & Grainger, 1990) would also be applicable to words in a language that not only does not use Roman letters and is, in fact, not based on letters at all. In particular, the present research examined these effects for Japanese Katakana, a syllabic-based language. Lecical decision latencies to word targets were significantly slower and more error prone when targets were primed by orthographic neighbors than when they were primed by unrelated words. Such was not the case, however, when targets were primed by nonword primes. These results suggest that lexical competition is not restricted to Indo-European languages. Instead, lexical competition is a more universal phenomenon that occurs in languages with different writing systems.

The clear difference in the pattern of priming effects from word and nonword neighbor primes not only suggests that lexical competition occurs for Katakana words(and therefore supports activation-based models of visual word recognition), but also suggests that each word corresponds to a discrete lexical representation. This idea, of course, does not follow PDP models that do not assumelexical-level local representations and do not predict an effect of prime lexicality.

The present study demonstrated that lexical competition also plays a significant role when reading Katakana words. What should be noted, of course, is that, although English and Katakana are obviously quite different, they do share some characteristics. Specifically, for both languages, the identification of a relatively restricted set of characters and that the correct calculation of relative character positions within a word are crucial for successful word identification. It is likely that it is these particular parallels between languages that led to the present results paralleling those in other languages, as well as leading toPerea and Pérez (2009) obtaining transposed-character priming effects in Katakanatransposed-letter priming effects in English (Perea & Lupker, 2003; 2004). These characteristics of Katakana are characteristics that are shared by other syllabic languages as well (e.g., Korean and Thai). Thus, it seems likely that the lexical competition would also be involved when reading these languages and, hence, there would be the inhibitory neighbor priming effects with these languages as well.

Chapter 3: Neighbor Priming with Japanese Kanji Compound Words: Do Masked Neighbor Primes Facilitate or Inhibit Target Processing in Logographic Scripts?

This chapter is based on

Nakayama, M., Sears, C. R., Hino, Y., & Lupker, S. R. (submitted).
Do Masked Orthographic Neighbor Primes Facilitate or Inhibit
Target Processing of Kanji Compound Words?

Overview

In Chapter 3, I will report the results of five experiments that tested neighbor priming effects with Japanese Kanji words. The purpose of this research was to determine if lexical competition is also applicable to the processing of logographic scripts, scripts that appear to be functionally different from alphabetic and syllabic scripts (i.e., Katakana). Kanji characters have characteristics that are distinctively different from Katakana characters and alphabetic letters. As will be discussed fully in the following section, notable characteristics of Kanji characters includes that for the most part, each Kanji character has multiple meanings and multiple readings. These aspects of Kanji characters were taken into consideration when predicting the effect from orthographic neighbor primes.

Experiment 3 was a straightforward test of the lexical competition process with Kanji words. In that experiment, higher-frequency neighbors primed lower-frequency targets and lower-frequency neighbors primed higher-frequency targets. All of the neighbor pairs were phonologically similar; the shared constituent was pronounced the same when it appeared in the prime and target. Experiment 4 was conducted similarly to Experiment 3, with one exception being that the neighbor pairs were not phonologically similar; the shared constituent was pronounced differently in the prime and target. In Experiment 5, nonword neighbor primed the same targets used in Experiment 3 to examine the effect of prime lexicality. Experiment 6 was a replication of

Experiments 3, 4, and 5 to assure the reliability of the results observed in these experiments. Finally in Experiment 7, morphological effects of the shared character were tested directly, by priming the targets used in Experiment 6 with the constituent character shared by their neighbor primes.

Characteristics of Kanji Characters

One of the unique characteristics of Kanji characters is that each Kanji character is a morpheme; a morpheme is the smallest meaningful unit in a language. Unlike both alphabetic letters and Katakana characters, each Kanji character has a set of specific meanings associated with it, and its exact meaning varies depending on the compound the character appears in. For example, the character 日 can mean either "sun", "Japan", or "a day" (e.g., 日照, "*sunshine*";日米, "*Japan and America*"; or 日中, "*in the day time*"), among other possibilities. In addition, a Kanji character is often ambiguous in terms of its meaning; in many circumstances, even a skilled reader of Japanese has difficulty identifying an exact meaning of a Kanji character (e.g., in a word such as 弁当, "*a lunch box*", it is not clear what each constituent character means).

Another notable characteristic of Kanji characters is that a Kanji character is a *logogram*, a written symbol that represents an entire spoken word without expressing its pronunciation. Unlike most Chinese characters, each of which has a single pronunciation (Verdonschot, Heij, Paolieri, Zhang, & Schiller, 2011; Verdonschot, Heij, & Schiller, 2010; Zhou & Marslen-Wilson, 1995), most Kanji characters have multiple pronunciations. How a Kanji character is pronounced depends on the context in which the character appears. In the case of the Kanji 日, it is read /ni/ when it appears in the word 日本 (/ni.ho.N/, “Japan”); /ni.ti/ when it appears in the word 日米 (/ni.ti.be.i/, “Japan and America”); and /hi/ when it appears in the word 日陰 (/hi.ka.ge/, “shade”).[8]

These aspects of a Kanji character, such that it has a set of meanings associated with it, and also that it has multiple pronunciations, clearly show that a Kanji character has different characteristics from a Roman letter. Even within the Japanese language, Kanji characters contrast sharply with Katakana characters. Katakana characters are not tied to a specific meaning and have a straightforward character-to-sound (character-to-mora) correspondence.

A Test of Lexical Competition Assumption with Kanji Neighbors

As discussed in Chapter 2, Katakana orthographic neighbor primes reliably inhibited target processing relative to unrelated primes (in Experiments 1A and 2). The significant interaction between Prime Type and Prime Lexicality in Experiments 1 and 2 suggests that such inhibition effects are due to processing at the lexical level. Consistent with the previous masked priming study that used English words with many neighbors (Nakayama et al.’s, 2008, Experiments 1 and 2), Experiment 1A found significant inhibition effects for Katakana neighbor pairs with many neighborsirrespective of relative prime-target frequency. Overall, the results of Katakana neighbor priming experiments are consistent with those reported in previous masked priming studies using alphabetic languages (Brysbaert et al., 2000; Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Duñabeitia, et al., 2009; Janack et al., 2004; Nakayama, et al., 2008; Segui & Grainger, 1990). Taken as a whole, the research illustrates that lexical competition is applicable to words in non-Roman scripts, at least to Japanese Katakana words.

What will be examined next is whether lexical competition applies to Kanji words, words that are very different from Roman words and Katakana words. In the present experiments, two-character Kanji compound words were selected as stimuli because two-character words represent about 80% of all Kanji words in the Japanese language (e.g., Hino & Lupker, 1998) and therefore reflect common Japanese vocabulary. As noted in Chapter 1, the classical definition of orthographic neighbors (Coltheart et al., 1977) was applied using a Kanji character as the orthographic unit. Kanji neighbors, therefore, had one character in common at the same position. For example, 国際 (“international”), 交際 (“companionship”), and 間際 (”on short notice”) were considered orthographic neighbors differing at the first character position, and 会議 (“conference”), 会釈 (“nodding/greeting”), and 会話 (“conversation”) were considered orthographic neighbors differing at the second character position. Using a 50 ms prime duration, the orthographic neighbor priming effect was assessed by comparing lexical decision performance to a target (e.g., 交際) that was primed either by an orthographic neighbor (e.g., 国際) or by an unrelated word (e.g., 制度).

Morphological Facilitation: A Possible Component of Kanji Neighbor Priming

There is one aspect of Kanji neighbors that is crucial to note. By definition, Kanji neighbors are words that share a constituent character. This fact means that Kanji neighbors are not only orthographically related, but are also morphologically related. That is, for Kanji compound words, each constituent character within a word is a morpheme. Hence, two-character Kanji neighbors always share a morpheme. Note thatthis is not to say that the shared character always denotes the same meaning when it appears in each of Kanji neighbors. Rather, by stating that Kanji neighbors are morphologically related, it implies that Kanji neighbors share an orthographic unit (a character) that represents the same set of meanings, and that the shared character may or may not denote the same meaning depending on the compound in which it appears. This aspect of Kanji neighbors, such that neighbors are not only orthographically related but also morphologically related, is something which is typically not true about neighbors in alphabetic languages.

According to Taft and colleagues (e.g., Taft, 2003; Taft, 2004; Taft & Kougious, 2004), when reading polymorphemic/compound words, two distinct processes are involved: 1) a visual stimulus is first decomposed into morphemes, and 2) the morphemes arethen integrated into a word at the whole-word level. That is, when processing a two-character Kanji compound, morphemic representations that correspond to each character would first be activated, and these morphemic representations would then be unified, activating a lexical representation at the whole-word level (i.e., a Kanji compound). Thus, in the case of masked Kanji neighbor priming, a possibility exists that a neighbor prime would pre-activate the same set of morphemic representations shared by a target and facilitate target identification (unlike neighbor primes in alphabetic languages). At the same time, Kanji neighbors are orthographically similar with each other, with each of them having distinct representations at the whole-word level. Therefore, if the lexical competition assumption is applicable to the processing of Kanji compounds, Kanji neighbor primes would inhibit target processing due to lexical competition, just like neighbor primes in alphabetic languages.

Masked morphological priming effects in alphabetic languages have now been documented in many different situations (e.g., Duñabeitia, Itziar, Perea, & Carreiras, 2008; Feldman, O'Connor, & Del Prado Martin, 2009; Fiorentino & Fund-Reznicek, 2009; Marslen-Wilson, Bozic, & Randall, 2008; Orfanidou, Davis, & Marslen-Wilson, 2011; Rastle & Davis, 2003; Rastle, Davis, & New, 2004; Shoolman & Andrews, 2003). For example, morphological facilitation has been shown to exist irrespective of the exact meaning of the shared morpheme represented in a prime and a target: an equivalent priming effect has been observed for semantically transparent prime-target pairs (e.g., departure–DEPART) and for semantically opaque prime-target pairs (e.g., department–DEPART) in many different languages (e.g., see Rastle & Davis, 2008, for a review).

Significant facilitory morphological priming effects for constituent prime-compound target pairs (e.g., jay–JAYWALK; book–BOOKSHOP) and for compound prime-constituent target pairs (e.g., teapot-TEA; honeymoon-HONEY) have also been documented (Shoolman & Andrews, 2003, and Fiorentino & Fund-Reznicek, 2009, respectively). These effects are not modulated by the position of the constituent (the constituent at first and second position primes compound targets equally well) or by the match/mismatch of the meanings of the constituent in a prime and a target.

More relevant to the present research, facilitation effects have also been observed for compound word prime – compound word target pairs (e.g., Duñabeitia et al., 2008). Duñabeitia et al. reported that lexical decisions were significantly facilitated when Basque compound targets were primed by different compounds that contained the same constituent, with equivalent effects for targets primed by a constituent in the first position (e.g., bookmark–BOOKSHOP) and in the second position (e.g., postman–MILKMAN). Facilitory priming was also observed when the shared constituent appeared in a different position in the prime and target (e.g., postman–MANKIND).

Thus, considering that a Kanji character is a morpheme, it seems likely that one will observe morphological priming for Kanji compounds as well.Therefore, the inhibitory effect of lexical competition, if it exists, may be counteracted to some degree by a facilitation effect due to the morphological overlap between the neighbor prime and target.

To my knowledge, there are no previous studies that have used the masked priming paradigm to look for evidence of lexical competition during the processing of Japanese Kanji compounds. The only study that is related to the current investigation is by Zhou, Marslen-Wilson, Taft, and Shu (1999) who used a masked priming procedure with two-character Chinese words as stimuli. Although the purpose of Zhou et al.'s experiments was not to examine the lexical competition process and, therefore, their stimuli were not optimally controlled for the strict test of lexical competition, they did use prime-target pairs with the same character in the same position. Thus, according to the definition of orthographic neighbors adopted here, their experiments involved the test of Chinese orthographic neighbors. Their results, then, should offer some insight into the effects of shared logographic character and of neighbor primes in logographic languages under the masked priming situation.

With masked 57 ms neighbor primes, Zhou et al. (1999) found a significant facilitory priming effect in their lexical decision experiments: targets were responded to faster when they were primed by their neighbors. This facilitation was observed when the common character denoted the same meaning in the prime and target (华丽 - 华贵, where the shared character both meant *splendid)* and also when the common character denoted different meanings in the prime and target (华桥 - 华贵, where the shared character meant *Chinese* and *splendid,* respectively*).*[9] Zhou et al. also found that such facilitory priming effects were not influenced by the position in which the common character occurred (the first or the second position), consistent with the findings of previous masked morphological priming studies in alphabetic languages (e.g., Duñabeitia et al., 2008; Shoolman & Andrews, 2003). In fact, similar to Duñabeitia et al., there was a facilitation effect even when the common character appeared in different positions in the prime and target (e.g., 笑容–容忍). These results show that responses to Chinese compound targets are facilitated by constituent character primes and support the idea that Chinese words can be primed morphologically. At the same time, clear facilitation effects observed from Chinese neighbor primes in their study seem to provide no evidence that lexical competition at the whole-word level plays a role when reading words in logographic scripts.

According to Zhou and Marslen-Wilson (2000), Zhou et al.'s (1999) results are easily accounted for by a model that employs "a distributed, connectionist framework, where orthographic, phonological, and semantic representations are viewed as activation patterns distributed over large numbers of simple processing units" (pp. 61). This type of model would predict that the priming effect for logographic scripts would be determined by the degree of featural overlap at orthographic, phonological, and semantic levels, and thus a facilitory priming effect would be expected from Chinese neighbor primes, as they would share orthographic, phonological, and possibly semantic features with their targets. On the other hand, because this type of model does not incorporate lexical representations at the whole-word level, as previously noted, there would be no obvious way to explain how a neighbor prime could produce an inhibition effect like that observed with alphabetic languages, if one had been obtained.

What is also true is that Zhou et al.'s (1999) facilitation effects can be readily explained by localist activation-based models, models that provide a clear explanation for the inhibitory neighbor priming effects observed with alphabetic languages (e.g., Grainger & Jacobs, 1996). In these models, unique lexical representations are assumed and competition via inhibition is assumed to operate at the lexical level. Therefore, according to these models, a neighbor prime (e.g.,貿易, "trade") would compete with a target (e.g., 簡易, "simple") at the lexical level, which would interfere with target processing. However, as suggested above, because neighbors in Chinese are also morphologically related, it's possible that this characteristic of logographic words would counteract any inhibitory effects of lexical competition.[10]Therefore, within a localist, activation-based framework, the facilitory effect from neighbor primes observed by Zhou et al. might be explained as the neighbor primes (e.g., 貿易) pre-activating shared morphemic representations of targets (e.g., 簡易). This facilitation may have cancelled out an inhibition effect at the lexical level.

Inhibition at the lexical level may be counteracted further by the semantic relatedness of neighbors at the whole-word level, as word pairs containing the same character may be more semantically similar than unrelated word pairs, especially when the shared character denotes the same meaning in the prime and target (Zhou et al., 1999). If so, this could produce a semantic priming effect, much like those observed in previous priming studies in Japanese and Chinese (e.g., Chen, Yamauchi, Tamaoka, & Vaid, 2007; Zhou et al., 1999).

Zhou et al.'s (1999) results are important in that they show that the shared character produces a facilitation effect, regardless of whether the character is used in the same meaning in the prime and target. At the same time, Zhou et al.'s results do not provide any conclusive evidence about lexical competition for logographic words, because, as noted earlier, their experiments were not designed to test the lexical competition assumption, and therefore did not address the factors that are important in testing this assumption. For one, Zhou et al. (1999) did not manipulate relative prime-target frequency: all of primes were lowerfrequency than the targets. Zhou et al. also did not report the number of neighbors for the stimuli. As noted previously, lower-frequency neighbor primes have a limited ability to inhibit target processing. This is especially true when the stimuli have a small number of neighbors (Nakayama et al., 2008). Lower-frequency neighbor primes can even produce a small (non-significant) facilitatory effect at times (Segui & Grainger, 1990, Experiment 2). Thus, it may have been that in Zhou et al.'s study, an inhibitory effect due to lexical competition was undermined.

For another, Zhou et al. (1999) did not test the lexicality of neighbor primes; their primes were always words. As there seems to be a greater source of facilitation in the neighbor priming of Chinese and Japanese Kanji words (i.e., morphological priming, in addition to orthographic and phonological priming) than alphabetic words, it is possible that the inhibition effect exists but its impact was counteracted by such facilitation components, resulting in overall facilitation. If that was true then facilitation effects should be even greater, if the same targets were primed by nonword neighbors. This is because the effect due to lexical competition would be greatly reduced (or even nonexistent) in this situation and therefore there would be no component to counteract such facilitation effects. To find out whether the lexical competition truly exists, it is important to contrast the priming effects from word and nonword neighbors primes.

The purpose of this research is to test the lexical competition assumption with Japanese Kanji neighbors. To this end, relative prime-target frequency of word neighbor pairs were manipulated (Experiments 3 and 4) and the effect of prime lexicality was examined (Experiments 5 and 6). In addition, the morphological facilitation component that may exist in Kanji neighbor priming was also tested directly using character-compound pairs (Experiment 7). Care was taken so that all of the word neighbor prime-target pairs were not highly semantically related, to reduce the semantic facilitation effect at the whole-word level.

The predictions were as follows: if the principles of activation-based models apply to Japanese Kanji compounds, then lexical competition would occur at the whole-word (lexical) level because Kanji neighbors, like neighbors in alphabetic languages and Katakana, are orthographically similar with each other, but yet they have distinct local representations at the lexical level. If so, Kanji neighbor primes would inhibit target processing. The inhibition effect may not be as strong as those observed in previous studies in alphabetic languages and Katakana, however, because additional source of facilitation is likely to exist in Kanji neighbor priming (because Kanji neighbors are also morphologically related). Even so, it was expected that the pattern of priming effects would be significantly different when targets were primed by word neighbors and by nonword neighbors.

On the other hand, if the lexical competition does not exist, and that PDP-type models better describe the reading processes of Kanji compounds, then Kanji neighbor primes would significantly facilitate target processing. It was also expected that prime lexicality would not change the pattern of the priming effects significantly. The present experiments were designed to explore these contrasting theories, using two-character Japanese Kanji compounds.

Experiment 3

Experiment 3 was a straightforward attempt to determine the effects of Kanji neighbor primes using a masked priming lexical decision task. Although orthographically-similar prime and target pairs always contained a shared constituent character (e.g., 女性ー酸性), an attempt was made to select pairs with minimal semantic similarity at the whole-word level. Also examined was the effect of phonological similarity of the shared character between the neighbor prime and target. In Experiment 3, the shared constituent character was always pronounced the same when it appears in the prime and target.

Method

Participants. Forty undergraduate students from Waseda University participated in this experiment. All were native speakers of Japanese and reported having normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli. All the stimuli were two-character Kanji compounds. Forty pairs of orthographic neighbors were selected as the critical stimuli. Neighbor pairs that were semantically related at the whole-word level were avoided as much as possible based on the author's intuition. For each pair, each neighbor served as either a prime or a target depending on the condition the pair was assigned to. To manipulate relative prime-target frequency, one member of the neighbor pair was much higher in normative frequency (*M* = 277.2, NTT Database; Amano & Kondo, 2000) than the other (*M* =

3.8).[11]All of these words had many orthographic neighbors: higher-frequency targets had a mean of 219.6 neighbors and lower-frequency targets had a mean of 226.3 neighbors.[12,] Of the 40 neighbor pairs, 21 pairs shared a Kanji character in the first character position and 19 pairs shared a Kanji character in the second character position. All of the shared Kanji characters had the same pronunciation.

The 40 neighbor pairs were divided into four groups that had similar mean word frequencies. The four types of prime-target pairs are as follows: 1) high-frequency neighbor prime – low-frequency target (e.g., 選手–助手), 2) high-frequency unrelated prime – low-frequency target (e.g., 影響–助手), 3) low-frequency neighbor prime – high-frequency target (e.g., 助手–選手), and 4) low-frequency unrelated prime – high-frequency target (e.g., 反響–選手).

Two of the four groups were used to create the orthographically-related conditions, one with the high-frequency member of the pair as the prime and the low-frequency member of the pair as the target, and the other with the prime-target pairings reversed. In the other two groups, unrelated prime-target pairs were created by reassigning the primes and targets within the group. Unrelated primes did not share any characters with their targets and, as in the two groups of related pairs, the high-frequency member of the pair was used as a target in one group and the low-frequency member was used as a target in the other. To counterbalance properly, each group of word pairs was assigned to the four conditions in a rotated manner and, as a result, four sets of word target pairs were created. The descriptive statistics for the stimuli are listed in Table 7. The word stimuli used in Experiment 3 are listed in Appendix D.

Forty nonword targets of two Kanji characters in length and with many neighbors (*M* = 208.9) were created for the lexical decision task. Nonwords were created by combining two Kanji characters randomly. Each nonword was paired with an orthographic neighbor with a large neighborhood (*M* = 201.2). Twenty nonwords were paired with high-frequency neighbors (*M* = 161.9) and the other 20 were paired with low-frequency neighbors (*M*= 2.7). To create the priming conditions for the nonwords, the 20 high-frequency neighbor prime–nonword target pairs were divided into two groups (of size 10) having similar prime word frequencies and neighborhood sizes; the 20 low-frequency neighbor prime–nonword target pairs were divided into two groups (of size 10) in a similar fashion. Unrelated prime–nonword target pairs were created by reassigning the primes and targets within the group. Unrelated primes did not share any characters with their targets. There were two counterbalancing sets of nonword target pairs. Each set of nonword target pairs was assigned to two of the four sets of the word target pairs and, hence, four stimulus sets were created, each assigned to the same number of participants.

Apparatus and procedure. These were the same as those used in Experiments 1 and 2.

Table 7

Mean Normative Frequency (per million occurrences) and Number of Neighbors of Stimuli Used in Experiment 3

Stimulus characteristic	Target	Neighbor prime	Unrelated prime
	Low frequency prime–high frequency target		
	選手 (seN.sju, sport player)	助手 (zjo.sju, assistant)	反響 (haN.kjou, echo)
Frequency	277.2	3.8	3.8
Neighbors	219.6	226.3	226.3
	High frequency prime–low frequency target		
	助手 (zjo.sju, assistant)	選手 (seN.sju, sport player)	影響 (ei.kjou, influence)
Frequency	3.5	277.1	277.1
Neighbors	224.0	219.6	219.6
	High frequency prime–nonword target		
	海泣	海外 (kai.gai, overseas)	法案 (hou.aN, draft law)
Frequency	–	161.9	161.9
Neighbors	208.0	200.1	200.1
	Low frequency prime–nonword target		
	手開	手首 (te.kubi, wrist)	永遠 (ei.eN, eternity)
Frequency	–	2.7	2.7
Neighbors	209.9	202.4	202.4

Results.

Data from participants with overall error rates greater than 20% were removed ($n = 4$) and replaced with four new participants who received the appropriate stimulus sets such that the proper counterbalancing of lists could be maintained across participants (the same procedure was followed in Experiments 4-7). Response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and were excluded from all analyses (less than 0.1% of word trials and less than 0.5% of nonword trials). In addition, for one low-frequency item (代休) the mean error rate was greater than 50%; the prime-target pairs including this item were excluded from all analyses.

For the word data, response latencies of correct responses and error rates were submitted to 2 (Prime Type: neighbor prime, unrelated prime) x 2 (Target Frequency: high, low) ANOVAs. In the subject analysis, both factors were within-subject factors. In the item analysis, Prime Type was a within-item factor, and Target Frequency was a between-item factor. The mean response latencies of correct responses and the mean error rates from the subject analyses are listed in Table 8.

For word targets, the main effect of Target Frequency was significant in the analysis of response latencies, $F_s(1, 39) = 153.80$, $p < .001$, $MSE= 2112.47$, partial $\eta^2 = .80$; $F_i(1, 76) = 79.27$, $p < .001$, $MSE = 4894.50$, partial $\eta^2 = .51$, and in the analysis of errors, $F_s(1, 39) = 92.43$, $p < .001$, $MSE= 77.42$, partial $\eta^2 = .70$; $F_i(1, 76) = 31.47$, $p < .001$, $MSE = 233.23$, partial $\eta^2 = .29$. Lexical decisions to high-frequency targets (primed by low-frequency

Table 8

Experiment 3: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets Primed By Words

	Word targets			
Prime type	High-frequency prime–low-frequency target		Low-frequency prime–high-frequency target	
	RT	Errors	RT	Errors
Neighbor	603	18.0	514	2.5
Unrelated	606	12.8	515	1.5
Difference	3	-5.2	1	-1.0

	Nonword targets			
Prime type	High-frequency prime		Low-frequency prime	
	RT	Errors	RT	Errors
Neighbor	640	7.0	645	7.5
Unrelated	638	8.0	640	8.3
Difference	-2	1.0	-5	0.8

words) were faster and more accurate (515 ms and 2.0% errors) than lexical decisions to low-frequency targets (primed by high-frequency words) (605 ms and 15.4% errors).

The main effect of Prime Type was significant in the analysis of errors, $F_s(1, 39) = 5.28$, $p < .05$, $MSE=73.96$, partial $\eta^2 = .12$; $F_i(1, 76) = 4.31$, $p < .05$, $MSE = 92.95$, partial $\eta^2 = .05$, but not in the analysis of response latencies (both Fs < 1). Error rates were higher when targets were primed by orthographic neighbors (10.3%) than when they were primed by unrelated words (7.1%). Although the effect of Prime Type in the error data was larger for low-frequency targets (5.2%) than for high-frequency targets (1.0%), the interaction between Prime Type and Target Frequency was not significant, $F_s(1, 39) = 2.61$, $p> .10$; $F_i(1, 76) = 1.99$, $p> .10$. There was no hint of an interaction in the analysis of response latencies (both $Fs< 1$). Response latencies were virtually identical when targets were primed by orthographic neighbors and when they were primed by unrelated words (559 ms and 561 ms, respectively), and this was true regardless of relative prime-target frequency.

For the nonword targets, response latencies and error rates were analyzed with 2 (Prime Type: neighbor prime, unrelated prime) x 2 (Prime Frequency: low, high) factorial ANOVAs. In the subject analysis, both factors were within-subject factors. In the item analysis, Prime Type was a within-item factor and Prime Frequency was a between-item factor, for both the analyses of response latencies and errors. In these analyses, there was no effect of Prime Type, Prime Frequency, or their interaction (all *F*s < 1).

Discussion

In Experiment 3, we examined whether an inhibitory or a facilitory neighbor priming effect arises for two-character Kanji neighbor pairs. If lexical competition plays essentially no role in the reading of Kanji compounds, then a facilitory priming effect would have been expected, analogous to the results obtained by Zhou et al. (1999) using two-character Chinese compounds as stimuli. Contrary to this prediction, we observed no effect on latencies and a small inhibitory priming effect on error rates. The inhibitory priming effect on error rates could be interpreted as evidence of lexical competition during the reading of Kanji compounds. At the same time, however, the absence of such an effect on response latencies suggests that lexical competition may not be as robust for Kanji words as for English words (Davis & Lupker, 2006; Nakayama et al., 2008) or Japanese Katakana words (Nakayama et al., 2011).

Experiment 4

Unlike the previous studies that investigated orthographic neighbor priming effects in alphabetic languages (Brysbaert et al., 2000; Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Duñabeitia, et al., 2009; Janack et al., 2004; Nakayama, et al., 2008; Segui & Grainger, 1990) and Katakana words (Nakayama et al., 2011), the results of Experiment 3 did not reveal an inhibitory priming effect on response latencies. However, there was a significant inhibitory effect on error rates to lower-frequency targets primed by higher-frequency neighbor primes, indicating that lexical competition may indeed play a role when reading Kanji compounds. The results supporting such an interpretation also come from the analyses of response latencies in Experiment 3: although no significant inhibition effect was observed for response latencies, the priming effects were essentially null (i.e., responses were not facilitated by neighbor primes, either). If lexical competition actually played no role in this situation, the prime-target similarity at the orthographic/phonological and morphemic levels should have produced a fairly large facilitation effect. A reasonable explanation for the null effect, therefore, is that although these factors produced a facilitory effect, that effect was counteracted by the inhibitory priming effect at the whole-word level. If this interpretation is correct, it should be possible to obtain stronger evidence of lexical competition if one further reduces the facilitory effects.

Zhou et al.'s (1999) experiments provide one idea of how to reduce the facilitory priming effects. In contrast to the significant facilitory priming effect observed in their Experiments 1, 2 and 3, Zhou et al. (1999) did not observe a priming effect in their Experiment 4B, when the shared character between the prime and target was pronounced differently (e.g., 重复(chong[2]fu[4], "repeat") – 重量(zhong[4]liang[4], "weight")). Moreover, there was an inhibitory trend in the error rates, as targets primed by these neighbor primes produced more errors (6.6%) than targets primed by unrelated primes (3.5%). These results indicate that, at least for Chinese compounds, the facilitory priming effect is substantially reduced when the character shared by the prime and target is pronounced differently. In Experiment 3, the shared constituent character was always pronounced the same when it appeared in the prime and target. It was hypothesized that, given Zhou et al.'s results, if neighbor pairs are used in which the shared constituent character is pronounced differently in the prime and target, this might increase the chance of observing an inhibition effect. Thus, Experiment 4 involved Kanji neighbor pairs in which the shared constituent character was pronounced differently when it appeared in the prime and target.

Method

Participants.Forty-four undergraduate students from Waseda University participated in this experiment. All were native speakers of Japanese and reported having normal or corrected-to-normal vision. None of these students participated in any of the previous experiments.

Stimuli.All the stimuli were Kanji words of two characters in length. Forty pairs of orthographic neighbors were selected as the critical stimuli. The important difference from Experiment 3 was that the shared constituent character was pronounced differently in the prime and target in the present experiment. To avoid uncontrolled differences in the lexical characteristics of the stimuli, all but two of the high-frequency neighbors used in Experiment 3 were used again, this time paired with newly selected low-frequency neighbors that had no overlapping phonology. As in Experiment 3, the use of highly semantically-related neighbor pairs was avoided based on the author's intuition. Of the 40 critical neighbor pairs, 20 had an overlapping Kanji character in the first character position and 20 had an overlapping Kanji character in the second character position. The mean normative frequency of the high-frequency neighbors was 280.9 and for the low-frequency neighbors it was 3.1. High-frequency words had a mean of 225.8 neighbors and low-frequency words had a mean of 258.9 neighbors. The descriptive statistics for the stimuli used in Experiment 4 are listed in Table 9.

Using the 40 neighbor pairs, four sets of word-target pairs were created in the same manner as in Experiment 3. The two sets of nonword target pairs used in Experiment 3 were also used in this experiment. Each set of nonword target pairs was added to two of the four sets of word target pairs in order to create four stimulus sets. The assignment to a stimulus set was counterbalanced across participants. The word pairs used in Experiment 4 are listed in Appendix E.

Apparatus and procedure. These were identical to those used in the previous experiments.

Table 9

Mean Normative Frequency (per million occurrences) and Number of Neighbors of Stimuli Used in Experiment 4

	Target	Neighbor prime	Unrelated prime
	Low-frequency prime–high-frequency target		
	選手 (se.N.sju, sport player)	右手 (mi.gi.te, right hand)	検事 (ke.N.zi, prosecutor)
Frequency	280.9	3.1	3.1
Neighbors	225.8	258.9	258.9
	High-frequency prime–low-frequency target		
	右手 (mi.gi.te, right hand)	選手 (se.N.sju, athlete)	仕事 (si.go.to, job)
Frequency	3.1	280.9	280.9
Neighbors	258.9	225.8	225.8

Results

As in Experiment 3, participants with overall error rates greater than 20% were replaced ($n = 1$) and response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and were excluded from all analyses (less than 0.5% of the word trials and less than 0.6% of nonword trials). In addition, for one lower-frequency target (反物), the mean error rate was greater than 50%; the prime-target pairs including this item were excluded from all analyses. The mean response latencies of correct responses and the mean error rates from the subject analyses are listed in Table 10. For the word and nonword data, the subject and item analyses of response latencies and errors were carried out in the same manner as described in Experiment 3.

The pattern of the results was very similar to that observed in Experiment 3. For word targets, the main effect of Target Frequency was significant in both the analysis of response latencies, $F_s(1, 43) = 106.91$, $p < .001$, $MSE = 1790.60$, partial $\eta^2 = .71$;$F_i(1, 76) = 40.49$, $p < .001$, $MSE = 5250.49$, partial $\eta^2 = .35$, and of errors, $F_s(1, 39) = 139.83$, $p < .001$, $MSE = 53.74$, partial $\eta^2 = .77$; $F_i(1, 76) = 26.91$, $p < .001$, $MSE = 260.32$, partial $\eta^2 = .26$. Lexical decisions to high-frequency targets were faster and less error prone (532 ms and 2.8% errors) than lexical decisions to low-frequency targets (599 ms and 15.8% errors). As was the case in Experiment 3, there was no main effect of Prime Type in the analysis of response latencies (both $Fs < 1$); response latencies to targets primed by orthographic

Table 10

Experiment 4: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets Primed by Words

	Word targets			
Prime type	High-frequency prime–low-frequency target		Low-frequency prime–high-frequency target	
	RT	Errors	RT	Errors
Neighbor	597	18.6	532	3.0
Unrelated	600	13.0	533	2.5
Difference	3	-5.6	1	-0.5

	Nonword targets			
Prime type	High-frequency prime		Low-frequency prime	
	RT	Errors	RT	Errors
Neighbor	630	8.0	630	10.9
Unrelated	627	9.5	620	8.4
Difference	-3	1.5	-10	-2.5

neighbors (565 ms) were virtually identical to those to targets primed by unrelated words (567 ms). The main effect of Prime Type was, however, significant in the analysis of errors, as it was in Experiment 3, $F_s(1, 43) = 4.80$, $p < .05$, $MSE= 86.30$, partial $\eta^2 = .10$; $F_i(1, 76) = 5.51$, $p < .05$, $MSE= 70.07$, partial $\eta^2 = .07$. Once again, error rates were higher when targets were primed by orthographic neighbors (10.8%) than when they were primed by unrelated words (7.8%).

Unlike Experiment 3, the interaction between Target Frequency and Prime Type was significant in the analyses of errors, $F_s(1, 43) = 4.58$, $p < .05$, $MSE= 65.68$, partial $\eta^2= .10$, $F_i(1, 76) = 4.00$, $p < .05$, $MSE= 70.07$, partial $\eta^2 = .05$. Follow-up comparisons revealed that there was an inhibitory priming effect only for low-frequency targets primed by high-frequency neighbors (a 5.6% effect), $t_s(43) = 2.31$, $p < .05$, $SEM = 2.46$; $t_i(38) = 2.36$, $p < .05$, $SEM = 2.46$. For high-frequency targets primed by low-frequency neighbors, the difference was only 0.5% (both ts < 1).

For the nonword targets, for both the analysis of response latencies and errors, there was no effect of Prime Type, Prime Frequency, or their interaction (all ps > .10).

Combined Analyses with Experiment 3

Although the results of this experiment appear to be very similar to those of Experiment 3, combined analyses were carried our for the data from the two experiments to look for possible differences. For the error data, the interaction between Target Frequency and Prime Type was significant, $F_s(1, 82) = 6.99$, $p < .05$, $MSE = 67.30$, partial $\eta^2 = .08$; $F_i(1, 152) = 5.65$, $p < .05$, $MSE = 81.51$, partial $\eta^2 = .04$, and there was no three-way interaction between Experiment, Target Frequency, and Prime Type (both Fs < 1), even though the Target Frequency x Prime Type interaction was significant only in Experiment 4. Follow-up comparisons revealed a significant inhibitory priming effect for low-frequency targets primed by high-frequency neighbors, $F_s(1, 82) = 9.74$, $p < .01$, $MSE = 128.52$, partial $\eta^2 = .11$; $F_i(1, 76) = 8.88$, $p < .01$, $MSE = 137.99$, partial $\eta^2 = .11$, but not for high-frequency targets primed by low-frequency neighbors, $F_s(1, 82) = 1.15$, $p > .10$; $F_i < 1$. These results support the conclusion that relative prime-target frequency plays a significant role in neighbor priming in Kanji. It must be kept in mind, however, that the error rates to high-frequency targets were quite low in both experiments, and the interaction might merely be the consequence of a floor effect for high-frequency targets.

The only significant interaction involving the Experiment factor in the combined analyses was the interaction between Experiment and Target Frequency in the subject analysis of response latencies, $F_s(1, 82) = 6.30$, $p < .05$, $MSE = 1943.68$, $\eta^2 = .07$; $F_i(1, 152) = 2.58$, $p > .10$, reflecting the fact that the word frequency effect was larger in Experiment 3 (90 ms) than in Experiment 4 (66 ms).

Discussion

In Experiment 4, Kanji neighbors that did not share phonology were selected as stimuli (i.e., the shared character had different pronunciations in the prime and target).

Regardless of this potentially important difference, the results of Experiment 4 were very similar to those of Experiment 3 — response latencies to targets were virtually identical when they were primed by neighbors versus unrelated words, but there was a significant inhibitory priming effect on error rates.

Thus, the inhibitory priming effect on error rates was observed with two different sets of low-frequency targets, as different sets of low-frequency targets were used in Experiments 3 and 4. This inhibitory priming effect could be interpreted as reflecting the operation of a lexical competition process during the reading of Kanji compounds. At the same time, however, the absence of such an effect on response latencies suggests that the competition process is not as robust as it is in alphabetic languages (e.g., Segui & Grainger, 1990; Davis & Lupker, 2006; Nakayama et al., 2008), which can be explained by the fact that Kanji neighbors have a greater source of facilitation relative to neighbors in those languages.

In Experiment 3, the shared constituent character had the same pronunciation in the prime and target, whereas in Experiment 4, the shared character had different pronunciations in the prime and target. Despite this potentially important difference, the results of Experiment 4 were very similar to those of Experiment 3. Unlike Experiment 3, in Experiment 4, the inhibitory priming effect on error rates was statistically significant only for low-frequency targets primed by high-frequency primes. Nonetheless, the data patterns were quite similar in the two experiments, with the inhibitory priming effect sizes being 5.2% and 5.6% when words were primed by higher-frequency neighbors and 1.0% and 0.5% when words were primed by lower-frequency neighbors in Experiments 3 and 4, respectively. The similar results of the two experiments clearly indicate that the shared phonology between neighbor pairs does not affect the priming effect from neighbor primes. This issue will be further addressed in the General Discussion.

Replicating the results of Experiment 3, the results of Experiment 4 did not reveal an inhibitory priming effect on response latencies. At the same time, again, there was no facilitation effect either. If lexical competition actually played no role in this situation, then prime-target similarity at the orthographic and morphemic levels should have produced a fairly large facilitation effect. Thus, the results of Experiments 3 and 4 lend no support to a PDP-type account of compound word recognition, because there was no evidence of a facilitory priming effect despite the fact that the neighbor primes have orthographic overlap with the targets. Moreover, the fact that the priming effect was not modulated by the phonological overlap between the prime and target (i.e., whether or not the shared constituent character in the prime and target was pronounced the same) is also inconsistent with a PDP-type account of compound word recognition, because the straightforward prediction of the PDP-type models would be more facilitation for phonologically similar prime-target pairs.

Once again, the results of Experiments 3 and 4 could, however, be accommodated by localist activation-based models by assuming two counteracting effects at different levels of processing: a facilitory effect due to morphemic similarity and an inhibitory effect due to lexical competition. Because the morphemic (and, potentially, orthographic) overlap due to the shared character in the neighbor pair would produce facilitory priming, any inhibitory priming effect due to lexical competition would be reduced or even eliminated. If these assumptions are true, then one prediction is that there should be a significant facilitory priming effect from nonword Kanji neighbors (i.e., two-character Kanji nonword primes that share one constituent character with two-character Kanji compound word targets at the same character position, for example, 内火 – 内縁, "common-law"). That is, because nonword neighbor primes would not have a representation at the whole-word level, when a nonword neighbor primes a word target, no lexical inhibition would be expected, allowing facilitation processes to dominate.

In contrast, PDP models do not incorporate localist representations at the morphemic and lexical levels, and so there would appear to be no a priori reason for this type of framework to predict different results for word and nonword neighbor primes. As such, Kanji nonword neighbor primes would be expected to produce no facilitation in terms of latencies as well as the same small inhibitory priming effect on error rates that was observed in Experiments 3 and 4. The purpose of Experiment 5 was to examine the effect of Kanji nonword neighbor primes in order to test the predictions of these two accounts.

Experiment 5

Method

Participants. The participants were 40 undergraduate students from Waseda University. All participants were native speakers of Japanese and reported having normal or corrected-to-normal vision. None of these students had participated in any of the previous experiments.

Stimuli.Forty pairs of Kanji compounds were selected to serve as targets. These were the same neighbor pairs used in Experiment 3, except that one low-frequency item that produced a high error rate (代休) was replaced by a new item (代行). Like the stimulus pairs used in Experiment 3, one member of the neighbor pair had a much higher normative frequency than the other (M = 277.2 vs. M = 4.3). The high- and low-frequency words were matched on the number of neighbors (M = 219.6 vs. M = 225.0). Forty nonword neighbors that shared a constituent character at the same position as the word neighbors were created to serve as primes. Both members of each neighbor pair were primed by the same nonword neighbor (only one member of the pair was presented to the same participant). The nonword primes had a similar number of neighbors as the word stimuli (M = 224.3). The descriptive statistics for the stimuli used in Experiment 5 are listed in Table 11 and the stimulus pairs used in Experiment 5 are listed in Appendix F.

As was done in the previous experiments, the neighbor pairs were divided into four groups that had similar average frequencies. Two of the groups were used to create the orthographically-related conditions, one involving the low-frequency member of the pair as the target and the other involving the high-frequency member of the pair as the target. Unrelated prime-target pairs were created in the other two groups by re-assigning the prime-target pairs within the group. Unrelated primes did not share any characters with their targets.

As such, there were four prime-target conditions: 1) nonword neighbor prime – low-frequency target (e.g., 鉄手 – 助手, “assistant”), 2) unrelated nonword prime – low-frequency target (e.g., 犬響 – 助手, “assistant”), 3) nonword neighbor prime – high-frequency target (e.g., 鉄手 – 選手, “athlete”), and 4) unrelated nonword prime – high-frequency target (e.g., 犬響－選手, “athlete”).

Of the 40 critical neighbor pairs, 22 pairs shared a Kanji character in the first character position and 18 pairs shared a Kanji character in the second position. The assignment of groups to conditions was counterbalanced across participants.A set of forty nonwords, the same nonwords used in the previous experiments, were also presented as targets. In addition, 40 nonword neighbors were newly created to

Table 11

Mean Normative Frequency (per million occurrences) and Number of Neighbors of Stimuli Used in Experiment 5

Stimulus characteristic	Target	Neighbor prime	Unrelated prime
	High-frequency target and nonword prime		
	選手 (/se.N.sju/, athlete)	鉄手	犬響
Frequency	277.2	–	–
Neighbors	219.6	228.3	228.3
	Low-frequency target and nonword prime		
	助手 (/zjo.sju/, assistant)	鉄手	犬響
Frequency	4.3	–	–
Neighbors	225.0	224.3	224.3
	Nonword target and nonword prime		
	手開	手退	永低
Frequency	–	–	–
Neighbors	208.9	218.0	218.0

serve as primes so that the lexicality of the prime was not indicative of the lexicality of the target. Each target was paired with a nonword orthographic neighbor with a large neighborhood (*M* = 218.0). To create the priming conditions for the nonword target trials, the nonword neighbor prime – nonword target pairs were divided into two groups (of size 20). Unrelated nonword prime–nonword target pairs were created by replacing the original primes by other nonwords. There were two counterbalancing lists for nonword target trials.

Apparatus and procedure. These were identical to those in the previous experiments.

Results

To be consistent with Experiments 3 and 4, original participants with overall error rates greater than 20% (*n* = 4) were replaced and response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and excluded from all analyses (less than 0.2% of word trials and less than 1.0% of nonword trials). For one low-frequency target (砂金), the mean error rate was greater than 50%. Thus, the prime-target pairs including this item were excluded from all the analyses.

For the word target data, response latencies of correct responses and error rates were submitted to 2 (Prime Type: neighbor prime, unrelated prime) x 2 (Target Frequency: low, high) factorial ANOVAs. In the subject analysis, both factors were within-subject factors. In the item analysis, Prime Type was a within-item factor and

Target Frequency was a between-item factor. For the nonword target data, Prime Type was the only factor in the ANOVAs. The mean response latencies of correct responses and the mean error rates from the subject analyses are listed in Table 12.

For word targets, the main effect of Target Frequency was significant in the analysis of response latencies, $F_s(1, 39) = 174.51$, $p< .001$, $MSE = 1647.70$, partial $\eta^2 = .82$; $F_i(1, 77) = 63.32$, $p < .001$, $MSE = 5274.57$, partial $\eta^2 = .45$, and the analysis of errors, $F_s(1, 39) = 42.86$, $p< .001$, $MSE = 63.53$, partial $\eta^2 = .52$; $F_i(1, 77) = 26.66$, $p < .001$, $MSE = 107.61$, partial $\eta^2 = .26$. Responses to high-frequency targets were faster and more accurate (544 ms and 2.4% errors) than responses to low-frequency targets (629 ms and 10.7% errors).

Unlike in Experiments 3 and 4, the main effect of Prime Type was significant in the analyses of response latencies, $F_s(1, 39) = 8.37$, $p < .01$, $MSE = 1054.11$, partial $\eta^2 = .18$; $F_i(1, 77) = 5.22$, $p < .05$, $MSE = 1568.61$, partial $\eta^2 = .06$. Overall, targets were responded to faster when they were primed by nonword neighbors (579 ms) than when they were primed by unrelated nonwords (594 ms). In addition, the interaction between Target Frequency and Prime Type was also significant in the analysis of response latencies, $F_s(1, 39) = 6.20$, $p < .05$, $MSE = 1497.69$, partial $\eta^2 = .14$; $F_i(1, 77) = 5.48$, $p < .05$, $MSE = 1568.61$, partial $\eta^2 = .07$.

Follow-up comparisons revealed that the nonword neighbor primes produced a significant 30 ms facilitory priming effect for low-frequency targets, $t_s(39) = 3.26$, $p < .01$, $SEM = 9.23$; $t_i(38) = 2.69$, $p < .05$, $SEM = 10.83$. For high-frequency targets, on the other

Table 12

Experiment 5: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets Primed by Nonwords

	Word targets			
Prime type	Nonword prime–low-frequency target		Nonword prime–high-frequency target	
	RT	Errors	RT	Errors
Neighbor	614	11.0	544	2.5
Unrelated	644	10.3	544	2.3
Difference	30	-0.7	0	-0.2

	Nonword targets	
	RT	Errors
Neighbor	645	7.5
Unrelated	660	6.0
Difference	15	-1.5

hand, there was no facilitory priming effect (both *t*s < 1), with the mean response latencies to targets primed by neighbor primes and by unrelated primes being identical (544 ms). For errors, there was no effect of Prime Type, nor was there an interaction between Target Frequency and Prime Type (all *F*s < 1).

For nonword targets, the only significant effect was the main effect of Prime Type in the analysis of response latencies, $F_s(1, 39) = 5.00$, $p < .05$, $MSE = 819.65$, partial $\eta^2 = .11$, $F_i(1, 39) = 4.31$, $p < .05$, $MSE = 1011.22$, partial $\eta^2 = .10$. Nonword targets were responded to faster when they were primed by nonword neighbors (645 ms) than when they were primed by unrelated nonwords (660 ms).

Discussion

The results of this experiment clearly show that the Kanji nonword neighbor primes produce a different pattern of priming effects than the Kanji word neighbor primes used in Experiments 3 and 4. More specifically, when targets were primed by nonword neighbors there was a significant facilitory priming effect that was restricted to the low-frequency targets, in contrast to the inhibitory priming effect on error rates observed in Experiments 3 and 4. According to the localist activation-based models, a nonword does not have a representation at the whole-word lexical level. Thus, upon presenting a nonword neighbor prime, although some lexical activation would be created, no single lexical representation would be strongly activated. In addition, there would, of course, be activation of orthographic and morphemic representations that correspond to the constituent characters. Thus, if the impact of word neighbor primes in Experiments 3 and 4 consisted of a facilitory component due to the orthographic and morphemic similarity and an inhibitory component due to lexical competition, then nonword neighbor primes should facilitate target processing because nonwords have very limited ability to produce lexical competition.

As such, taken together, the facilitory priming effect from nonword neighbor primes in Experiment 5, along with the null effect on response latencies and the small inhibitory priming effect on error rates from word neighbor primes in Experiments 3 and 4, is consistent with the idea that lexical competition does play a role in the reading of Kanji compounds. On the other hand, the different patterns of priming effects with word and nonword primes is not consistent with the PDP-type account of compound word recognition, because this type of account would predict that the priming effects should be equivalent regardless of the lexicality of the primes.

Experiment 6

The purpose of Experiment 6 was to assess the generality of the data patterns observed in Experiments 3, 4, and 5. To do so, a new set of stimuli was selected and the effect of prime lexicality (word vs. nonword) was tested in a single experiment. In this experiment, only low-frequency targets were used because the priming effects were limited to low-frequency targets in the previous experiments. Thus, a low-frequency target was preceded by four different types of primes: a word neighbor prime, an unrelated word prime, a nonword neighbor prime, and an unrelated nonword prime.

Recall that in Experiments 3 and 4, the use of semantically-related word pairs was avoided, to the extent possible, with the decisions about whether the prime-target pairs were semantically similar being based only on the author's intuition. Thus, it is not impossible that the semantic relatedness may not have been completely comparable for the word neighbor pairs and the unrelated word pairs. If the word neighbor pairs were somehow more semantically-related than the unrelated word pairs, lexical competition would have been more difficult to detect, because of the facilitation produced by semantic relatedness. In order to maximize the chance of observing an effect of lexical competition, in Experiment 6, semantic relatedness ratings were collected for the stimulus pairs in order to equate the neighbor and unrelated pairs on this dimension.

In addition, unlike in the previous experiments, a different set of unrelated primes were selected to create the unrelated pairs, rather than re-pairing neighbor prime-target pairs (a standard procedure in the masked priming literature). In the previous experiments, unrelated prime-target pairs were created by pairing a target with a neighbor prime of a different target. When using Kanji compound stimuli this procedure necessitates that all unrelated primes contain a constituent character that is shared by a target on a different trial. If the prior exposure to a constituent character (even though the presentation is masked) were to facilitate the identification of the target later in the trial block, lexical decision performance would be affected. Although it has been reported that the effect of masked primes is short-lived (up to 2-3 seconds, Ferrand, 1996; Forster & Davis, 1984; Versace & Nevers, 2003) and does not survive across many intervening trials (Humpreys, Besner, & Quinlan, 1988), a different set of unrelated primes was used to completely rule out the possibility that the repetition of characters across trials could affect the pattern of results that would be observed in Experiment 6.

The expectation was that the data from Experiment 6 would replicate the data from the preceding experiments (i.e., an inhibitory priming effect on error rates from word neighbors and a facilitory priming effect from nonword neighbors). If such results were indeed observed, they would provide additional confidence in the pattern of priming effects observed in Experiments 3, 4, and 5 and the conclusions derived from those results.

Method

Participants. The participants were 48 undergraduate students from Waseda University. All were native speakers of Japanese and reported having normal or corrected-to-normal vision. None of these students participated in any of the previous experiments.

Stimuli.Sixty-four two-character Kanji compounds were selected to serve as targets. All the targets were of lowfrequency, with a mean normative frequency of 5.5.

Targets had a mean of 52.8 orthographic neighbors. For each target (e.g., 支障, “trouble”), four types of primes were selected: 1) a word that was a higher-frequency orthographic neighbor of the target (e.g., 支持, “support”; these words had a mean normative frequency of 192.5), 2) an unrelated higher-frequency word (e.g., 責任, “responsibility”; these words had a mean normative frequency of 189.0), 3) a nonword that was an orthographic neighbor of the target (e.g., 支楽), and 4) an unrelated nonword (e.g., 責楽). The number of neighbors was matched closely for the four types of primes (*M* = 52.8, 48.9, 48.5, and 42.5 for the word neighbor primes, nonword neighbor primes, unrelated word primes, and unrelated nonword primes, respectively). The descriptive statistics for the stimuli are listed in Table 13 and the stimulus pairs are listed in Appendix G. The four prime-target conditions were as follows: 1) word neighbor prime – low-frequency target (e.g., 支持 – 支障), 2) unrelated word prime – low-frequency target (e.g., 責任– 支障), 3) nonword neighbor prime – low-frequency target (e.g., 支楽 – 支障), and 4) unrelated nonword prime – low-frequency target (e.g., 責楽ー支障). As noted, unlike the previous experiments, a different set of stimuli was used as unrelated primes (word and nonword) rather than re-pairing neighbor prime-target pairs.

In order to control the semantic relatedness of prime-target pairs, 44 undergraduate students from Waseda University (who did not participate in the lexical decision task) were asked to rate the semantic relatedness of the word prime-word target pairs (both neighbor pairs and unrelated pairs), using a 7-point scale (where 1 = *not semantically related at all*, and 7 = *strongly semantically related*). An analysis of these ratings indicated that the prime-target pairs were only weakly semantically related, and the mean relatedness ratings for neighbor pairs (2.4) and unrelated pairs (2.2) were not significantly different, $t_i(63) = 1.41$, $p > .10$.

For the targets primed by orthographic neighbors, 31 of the pairs had the shared character in the first position and 33 had the shared character in the second position. The shared character for the word neighbor primes had the same pronunciation in half of the pairs and different pronunciations in the other half of the pairs. Four counterbalancing lists were created for word targets, such that each target was primed by each of the four prime types. One-quarter of the participants saw each of the pairings.

Sixty-four two-character Kanji nonwords were created to serve as nonword targets. The nonword targets had a mean of 44.8 orthographic neighbors. For each nonword (e.g., 黄生), four types of primes were selected:1) a high-frequency word neighbor prime (e.g., 学生, "student"; these words had a mean normative frequency of 174.5), 2) a high-frequency unrelated word prime (e.g., 土地, "land"; these words had a mean normative frequency of 173.8), 3) a nonword neighbor prime (e.g., 師生), and 4) an unrelated nonword prime (e.g., 師地). As there were four prime-target conditions, four counterbalancing lists were created for the nonword targets, with each one being paired with one of the four lists created for the word targets.

Table 13

Mean Normative Frequency (per million occurrences) and Number of Neighbors of Stimuli Used in Experiment 6

	Target	Word neighbor prime	Word unrelated prime	Nonword neighbor prime	Nonword unrelated prime
Word targets					
	支障 (/sisjou/, trouble）	支持 (/size/, support)	責任 (/sekiniN/, responsibility)	支楽	責楽
Frequency	5.5	192.5	189.0	–	–
Neighbors	52.8	51.0	48.5	48.9	42.5
Nonword targets					
	黄生	学生 (/gakusei/, student)	土地 (/tocji/, land)	師生	師地
Frequency	–	174.5	173.8	–	–
Neighbors	44.8	45.9	49.8	42.3	43.9

Apparatus and procedure. These were identical to those in the previous experiments.

Results

Consistent with the previous experiments, original participants with overall error rates greater than 20% ($n = 9$) were replaced appropriately and response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and excluded from all the analyses (less than 0.8% of word trials and less than 0.7% of nonword trials). For one item (関脇), the mean error rate was greater than 50% and the prime-target pairs including this item were excluded from all the analyses. The mean response latencies of correct responses and the mean error rates were analyzed with 2 (Prime Lexicality: word prime, nonword prime) x 2 (Prime Type: neighbor, unrelated) factorial ANOVAs. The data for the word targets and the data for the nonword targets were analyzed separately. Prime Lexicality and Prime Type were within-subject factors in the subject analysis and within-item factors in the item analysis. The mean response latencies and error rates from the subject analyses are listed in Table 14.

For word targets, the main effect of Prime Lexicality was not significant in the analysis of response latencies or the analysis of errors (all *F*s < 1). The main effect of Prime Type was also not significant in the analyses of response latencies, $F_s(1, 47) = 2.75$, $p > .10$; $F_i < 1$, or the analyses of errors, $F_s(1, 47) = 1.15$, $p > .10$; $F_i < 1$. As expected, there was a significant interaction between Prime Lexicality and Prime Type, both for response latencies, $F_s(1, 47) = 7.42$, $p < .01$, $MSE = 920.25$, partial $\eta^2 = .14$; $F_i(1, 62) = 5.45$, $p < .05$, $MSE = 2118.00$, partial $\eta^2 = .08$, and for errors, $F_s(1, 47) = 17.33$, $p < .001$, $MSE = 46.61$,partial $\eta^2 = .27$; $F_i(1, 62) = 19.73$, $p < .001$, $MSE = 55.45$, partial $\eta^2 = .24$. Follow-up comparisons revealed that the interaction was due to the different impact of word and nonword primes on target responses. When targets were primed by word neighbors, they were responded to 3 ms slower than when they were primed by unrelated words, $t_s < 1$; $t_i(62) = 1.29$, $p > .10$. In contrast, when targets were primed by nonword neighbors, they were responded to 20 ms faster than when they were primed by unrelated nonwords, $t_s(47) = 3.06$, $p < .01$, $SEM = 6.55$; $t_i(62) = 2.05$, $p < .05$, $SEM = 7.85$. This interaction was slightly different in the error analysis but consistent with the response latency analysis: when targets were primed by word neighbors the mean error rate was higher than when targets were primed by unrelated words (a 5.3% inhibition effect), $t_s(47) = 3.62$, $p < .01$, $SEM = 1.48$; $t_i(62) = 3.05$, $p < .01$, $SEM = 1.78$, whereas for targets primed by nonword neighbors the mean error rate was somewhat lower than when they were primed by unrelated nonwords (a 2.9% facilitation effect), $t_s(47) = 1.84$, $p = .07$, $SEM= 1.56$; $t_i(62) = 1.75$, $p = .09$, $SEM = 1.67$. Both of these interactions, for response latencies and for errors, nicely replicate the patterns of priming effects observed for word and nonword neighbor primes in Experiments 3, 4 and 5.

For nonword targets, the only significant effect was the main effect of Prime Lexicality in the analyses of response latencies,$F_s(1, 47) = 7.03$, $p< .05$, $MSE = 1412.31$,

Table 14

Experiment 6: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets Primed by Words and Nonwords

	Word Targets			
Prime type	Word prime		Nonword prime	
	RT	Errors	RT	Errors
Neighbor	623	12.8	612	9.6
Unrelated	620	7.4	632	12.5
Difference	-3	-5.4	20	2.9

	Nonword Targets			
Prime type	Word prime		Nonword prime	
	RT	Errors	RT	Errors
Neighbor	676	9.0	656	6.5
Unrelated	672	7.2	663	7.2
Difference	-4	-1.8	7	0.7

partial$\eta2$ = .13; $F_i(1, 63) = 3.47$, $p = .07$, $MSE = 2261.72$, partial $\eta2$= .05. Averaging over Prime Type (neighbor vs. unrelated), targets were responded to 14 ms faster when primed by nonwords than when primed by words.

Discussion

Although Experiment 6 involved a new set of stimuli, a different experimental design, and a new group of participants, the results were entirely consistent with the results of Experiments 3, 4, and 5. Responses to targets were facilitated when they were primed by nonword neighbors, whereas responses to the same targets were inhibited when they were primed by word neighbors, although, once again, the latter effect was observed only on error rates. Although the results of the experiments do not illustrate a clear inhibitory priming effect for Kanji word neighbor primes on response latencies, the contrasting priming effects due to prime lexicality are analogous to the results reported in previous masked priming studies using English words (e.g., Davis & Lupker, 2006).

As noted previously, the absence of a clear inhibitory priming effect on response latencies in the word neighbor prime conditions could be due to the difference in morphemic structure for English words and Japanese Kanji words. The English words used by Davis and Lupker (2006) and Nakayama et al. (2008) were all monomorphemic words, whereas the Kanji words used in the present experiments were all polymorphemic/compound words.

According to Taft and colleagues (e.g., Taft, 2003; Taft, 2004; Taft & Kougious, 2004), a polymorphemic/compound word is first deconstructed into morphemes and then integrated in order to allow access to the whole-word level (lexical) representation. If so, the masked word neighbor primes in the experiments could have produced two opposing effects: facilitation at the morphemic and potentially orthographic and semantic levels and inhibition at the lexical level. In contrast, neighbor primes and targets in English are typically not morphemically or semantically related and, hence they do not provide morphemic or semantic priming, and therefore they are more likely provide a better opportunity to observe the inhibition effects due to lexical competition. Note that any facilitation at the semantic level should have been minimal in Experiment 6 because the semantic relatedness ratings were comparable for the word neighbor pairs and the unrelated word pairs. The facilitory priming effect in Experiment 6 would have been due only to morphemic (and possibly orthographic) similarity.

Experiment 7

The data from Experiments 3-6 can be explained if one assumes that inhibitory effects due to lexical competition are counteracted by morphemic (and possibly orthographic) facilitation. What should be noted, however, is that morphological priming effects have yet to be examined in the masked priming situation with Kanji compound words (in contrast to the extensive literature on morphological priming effects in alphabetic languages; e.g., Duñabeitia et al., 2008; Feldman et al., 2009;

Fiorentino & Fund-Reznicek, 2009; Marslen-Wilson et al., 2008; Orfanidouet al., 2011; Rastle et al., 2004). The purpose of the final experiment was to directly test for effects of morphological priming using Kanji compound words. We used the same word targets as used in Experiment 6, and each target (e.g., 支障, "trouble") was primed either by the same constituent character shared by their orthographic neighbor primes, (e.g., 支), or by an unrelated single character (e.g., 引). Semantic relatedness ratings were collected for single character prime-compound word target pairs (both for morphological and unrelated primes) to assess the effects of semantic transparency on the size of the morphological priming effect. If the assumption that lexical competition is counteracted by morphological facilitation is correct, then morphological primes (the constituent characters of the compound targets) should significantly facilitate target processing relative to unrelated primes. Further, consistent with previous masked morphological priming studies with alphabetic scripts, our expectations were that the size of the facilitation effects would not be significantly modulated by the semantic relatedness of the prime-target pairs (e.g., Marslen-Wilson et al., 2008; Orfanidou et al., 2011; Rastle et al., 2004; Rastle & Davis, 2008) nor by the position of constituent primes (e.g., Shoolman & Andrews, 2003).

Method

Participants. The participants were 36 undergraduate students from Waseda University. All were native speakers of Japanese and reported having normal or corrected-to-normal vision. None of these students participated in any of the previous experiments.

Stimuli.The same two-character Kanji compound words used in Experiment 6 served as targets, except for one item that was replaced due to a high error rate (関脇 was replaced by 芝居). Each target (e.g., 支障, “trouble”) was primed either by a morphological prime (e.g., 支) or by an unrelated single Kanji character (e.g., 引). For each of the word targets, the morphological prime was always the same constituent character that was shared by the neighbor pair in Experiment 6. For the morphological prime-target pairs, 31 of the targets were primed by their constituent character in the first position (e.g., 支－支障) and 33 were primed by their constituent character in the second position (e.g., 連－常連).

As in Experiment 6, we used a different set of stimuli as unrelated primes (word and nonword). The descriptive statistics for the stimuli are listed in Table 15 and the stimulus pairs are listed in Appendix G. The morphological primes and unrelated primes were matched in terms of the mean character frequencies (*M* = 1594 and 1545 occurrences per million, respectively; Amano & Kondo, 2000) and the mean number of strokes (*M* = 8.4 and 8.1). The mean orthographic complexity ratings for the two types of primes were identical (*M* = 3.5; using the ratings from the NTT database; Amano & Kondo, 2000). Two counterbalancing lists were created for word targets, such that each target was primed by each of the two prime types, with one-half of the participants seeing each of the pairings. Sixty-four two-character Kanji nonwords served as nonword targets (most of these nonword targets were also used in Experiment 6). Each nonword target (e.g., 黄生) was primed either by a constituent character (e.g., 黄) or an unrelated character (e.g., 元). The mean character frequencies for the two types of primes were 1104 and 1219 occurrences per million and the mean number of strokes were 8.7 and 8.8. The mean orthographic complexity ratings were identical (*M* = 3.5). Two counterbalancing lists were created for the nonword targets.

Apparatus and procedure.These were identical to those in the previous experiments.

Results

Consistent with the previous experiments, original participants with overall error rates greater than 20% (*n* = 1) were replaced appropriately and response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and excluded from all analyses (less than 0.5% of word trials and less than 1.4% of nonword trials). One item (反吐) was excluded from all the analyses because the mean error rate for this item was greater than 50%. The mean response latencies of correct responses and the mean error rates were analyzed with one-factor repeated measure ANOVAs (Prime Type: morphological, unrelated). The mean response latencies and error rates from the subject analyses are listed in Table 16.

Table 15

Mean Normative Character Frequency (per million occurrences), Number of Strokes of Morphological Primes and Unrelated Primes and Mean Normative Word Frequency of Word Targets Used in Experiment 7

	Target	Morphological prime	Unrelated prime
		Word targets	
	支障 (/sisjou/, trouble)	支	引
Strokes	–	8.4	8.1
Frequency	5.9	1594	1545
		Nonword targets	
	黄生	黄	元
Strokes	–	8.7	8.8
Frequency	–	1104	1219

Table 16

Experiment 7: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets Primed by Single Kanji Characters

Prime type	Word targets	
	RT	Errors
Morphological	568	7.0
Unrelated	599	12.1
Difference	31	5.1

Prime type	Nonword targets	
	RT	Errors
Morphological	645	10.9
Unrelated	637	7.6
Difference	-8	-3.3

For word targets, there was a significant facilitation effect from morphological primes, both in the analysis of response latencies, $F_s(1, 35) = 29.63$, $p < .001$, $MSE = 572.06$, partial $\eta^2 = .46$; $F_i(1, 62) = 33.81$, $p < .001$, $MSE = 1220.63$, partial $\eta^2 = .35$, and in the analysis of errors, $F_s(1, 35) = 23.96$, $p < .001$, $MSE = 19.05$, partial $\eta^2 = .41$; $F_i(1, 62) = 13.54$, $p < .001$, $MSE = 60.88$, partial $\eta^2 = .18$. Responses to word targets were faster and more accurate (568 ms and 7.0%) when they were primed by constituent characters than when they were primed by unrelated characters (599 ms and 12.1%).

For nonword targets, there was a significant inhibition effect on error rates, $F_s(1, 35) = 4.47$, $p < .05$, $MSE = 43.80$, partial $\eta^2 = .11$; $F_i(1, 63) = 8.34$, $p < .01$, $MSE = 41.51$, partial $\eta^2 = .12$, but not on response latencies, $F_s(1, 35) = 2.49$, $p > .10$; $F_i(1, 63) = 3.97$, $p = .05$, $MSE = 1187.9$, partial $\eta^2 = .06$. Responses to nonword targets were less accurate (10.9%) when they were primed by constituent characters than when they were primed by unrelated characters (7.6%).

To assess the effect of semantic relatedness of prime-target pairs on the pattern of morphological priming effects, 52 undergraduate students from Waseda University (who did not participate in the lexical decision task) rated the degree to which the single character primes were semantically related to their targets, using a 7- point scale (where 1 = *not semantically related at all*, and 7 = *strongly semantically related*).[13] As expected, morphologically related primes were rated as more semantically related (*M* = 4.4, *SD* = 1.1) to their targets than unrelated primes (*M* = 1.7, *SD* = 0.5), $t(63) = 18.13$, $p < .001$, *SEM* = .14. For each target, a semantic relatedness measure was created by subtracting the semantic relatedness rating for that target and its unrelated prime from the semantic relatedness rating for that target and its morphologically related prime. The semantic relatedness measures for the targets, calculated this way, ranged from 0.6 to 5.2 (*SD* = 1.2).These values were regressed on the size of morphological priming effects for each word target. In this analysis, semantic relatedness did not predict the size of the priming effect, for either response latencies, $t_i(62) = 1.06$, $p > .10$, or for errors, $t_i < 1$.

For word targets, the effect of the position of the constituent primes was also examined on the size of priming effects. To do so, we compared the mean priming effect (using item means) for targets primed by their first constituent character (*n* = 30, e.g., 支 – 支障) to the mean priming effect for targets primed by their second constituent character (*n* = 33, e.g., 連 – 常連). This analysis revealed that the position of the constituent character did not interact with the priming effect for response latencies, F_i (1, 61) = 1.34, $p > .10$, or for errors, $F_i < 1$.For targets primed by their first constituent character the facilitory priming effects were 29 ms and 4.7% and for targets primed by their second constituent the facilitory priming effects were 43 ms and 5.6%.[14]

Discussion

The key result in this experiment was the presence of a facilitory morphological priming effect: targets primed by one of their constituent characters were responded to significantly faster and more accurately than targets primed by an unrelated Kanji character. In addition, the size of the facilitation effect was not affected by the semantic relatedness of the prime-target pairs or by the position of the shared constituent. These results are consistent with the findings of other masked morphological priming studies (e.g., Fiorentino & Fund-Reznicek, 2009; Shoolman & Andrews, 2003). These findings indicate that morphological priming for compound Kanji words is similar to morphological priming for words in alphabetic scripts.

Recall that in Experiments 3, 4, and 6, an inhibitory priming effect from word neighbor primes was observed only in the errors rates to targets. This outcome was explaineddue to lexical competition being counteracted by morphological facilitation from shared constituent characters of neighbor pairs. In Experiment 7, this facilitory component was directly tested by priming each target used in Experiment 6 with the same single Kanji character that was shared by the neighbors in Experiment 6. Considering that the same targets produced contrasting effects in Experiment 6 (where primes were orthographic neighbors of the targets) and Experiment 7 (where primes were one of the constituent characters of the targets), it is concluded that the lack of facilitation observed in response latencies (and the significant inhibition effect observed in error rates) from word neighbor primes reflects inhibition effects counteracting facilitory morphological priming effects.

General Discussion: Kanji Words

The existence of competition among the lexical units of orthographically-similar words (i.e., orthographic neighbors) is one of the core assumptions of many localist activation-based models of word recognition (e.g., Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). One consequence of this architecture is the prediction that the processing of a target word will be delayed when a target is primed by a higher-frequency orthographic neighbor because of the heightened competition between the lexical unit of the target and that of the neighbor. On the other hand, in models that do not incorporate discrete lexical representations, such as PDP models (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1989) predict that target word processing is facilitated when a target is primed by an orthographically-similar prime(see Zhou & Marslen-Wilson, 2000).

Previous masked priming studies using alphabetic languages (e.g., Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990) are consistent with localist activation-based models: namely, in these studies, lexical decision responses to a target were slower when the target was primed by an orthographic neighbor than when it was primed by an unrelated word. In Experiments 1 and 2 in Chapter 2, a similar inhibitory neighbor priming effect was also observed using Japanese Katakana words, suggesting that the lexical competition process occurs in non-alphabetic languages as well. In contrast to the situation with alphabetic languages and Katakana words, far less is known of the impact of neighbor priming on the processing of words written in logographic scripts.

In the present research, therefore, the effect of masked priming was investigated using orthographic neighbors in Japanese Kanji, a logographic script. Although Kanji neighbors differ in some ways from neighbors in alphabetic languages, Kanji neighbors may still have the essential characteristics to create lexical competition; like neighbors in alphabetic languages, Kanji neighbors share characters and have distinct word-level representations. If lexical competition applies to the processing of Kanji words, then masked neighbor priming should result in inhibition. Another factor to consider is that Kanji neighbors are also morphologically related (unlike orthographic neighbors in alphabetic languages). Based on previous research examining the masked morphological priming effect (e.g., Duñabeitia et al., 2008; Shoolman & Andrews, 2003;

Zhou et al., 1999), a facilitory component was also expected in the Kanji neighbor priming effect due to the shared constituent character of neighbor primes and targets, which would counteract the lexical competition.

In Experiments 3, 4, and 6, there was evidence of a lexical competition process, although the relevant effects were always confined to error rates. These results do, of course, contrast to some degree with the previous masked priming studies with orthographic neighbors using alphabetic languages (e.g., Andrews & Hersch, 2010; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Nakayama et al., 2008; Segui & Grainger, 1990) and Katakana words (Nakayama et al., 2011). In these previous studies, the inhibition effects usually emerged in both response latencies and errors. Nonetheless, the present research found inhibitory effects on error rates across three different sets of stimulus materials and suggests that the effect is reliable. What is important to note is that the null priming effects from word neighbor primes on latencies (Experiments 3, 4 and 6) differs greatly from the clear facilitation effects from nonword neighbor primes (Experiments 5 and 6) and from single constituent character primes (Experiment 7). These differences provide additional support for the notion of an inhibitory mechanism involved in the neighbor priming effect in Kanji. Therefore, the lexical competition assumption of activation-based models extends to the word recognition processes involved in reading logographic scripts.

The Role of Phonology in the Kanji Orthographic Neighbor Priming Effect

One of the interesting aspects of the results of the present research was that the phonological similarity between prime-target pairs did not affect the pattern of neighbor priming effects (recall that the shared constituent character was pronounced the same in the prime and target in Experiment 3 and was pronounced differently in the prime and target in Experiment 4). The results of Experiments 3 and 4 raise the question as to why the phonological relationship between the prime and target was important in Chinese words (Zhou et al., 1999) and unimportant in Kanji words. The different results may reflect different processing of Chinese and Japanese compounds. Most Chinese characters have a single pronunciation (e.g., Verdonschot, et al., 2010; Verdonschot, et al., 2011; Zhou & Marslen-Wilson, 1995), and when a Chinese character is pronounced differently, it tends to have a different meaning. When reading Chinese compounds, morphemic/semantic activation is therefore guided strongly by phonology. In contrast, the majority of Kanji characters have multiple pronunciations. When a Japanese Kanji character is pronounced differently, it nevertheless tends to have the same meaning. For example, 親 is pronounced differently in the Kanji compound 両親 (/rjousiN/, "parents") and in the compound 母親 (/hahaoja/, "mother"). Regardless of the pronunciation difference, this Kanji character denotes the same meaning ("parent"). As such, the role of phonology in activating higher-level representations (morphemic/semantic) may be less important when reading Japanese Kanji words than when reading Chinese words. Thus, the phonological similarity of the shared character between the prime and target may play very little of a role in priming effects for Kanji words.

The Nature of Facilitory Priming in Kanji

As noted, a facilitory nonword neighbor priming effect has also been reported by most investigators who have used words in alphabetic languages (e.g., Davis & Lupker, 2006; Forster et al., 1987; Forster & Veres, 1998; Perea & Rosa, 2000) and in one set of experiments that used Katakana script (Experiments 1 and 2 in Chapter 2). In spite of this parallel to the present results, it seems likely that the facilitory effects observed in our experiments are somewhat different than the effects observed in those previous studies. In previous studies, the typical finding has been that nonword neighbor priming effects tend to arise for longer words and words with relatively low neighborhood densities (e.g., Davis & Lupker, 2006; Forster et al, 1987). In fact, as Davis and Lupker noted, these two factors may necessarily interact because a) longer words will, inevitably, have lower densities and b) the degree of orthographic overlap between a nonword neighbor prime and a target (and, hence, the potential for the prime to activate the target) is, by definition, greater for longer words than for shorter words.

In the present experiments, two-character Kanji compoundswere used as targets in both Experiments 5 and 6 and, hence, these targets were all high neighborhood density words (*M* = 222.3 in Experiment 5 and *M* = 52.8 in Experiment 6). In addition, only one character was shared with the primes, and thus the degree of orthographic overlap (50%) was lower than what is typically the case in experiments using English stimuli (typically 75% and higher). As a consequence, it would seem rather unlikely that the nonword neighbor priming effects in these experiments had exactly the same locus as those reported in the previous experiments using English stimuli. Rather, based on the fact that clear morphological priming effects were found (in Experiment 7) and that, with two-character Kanji stimuli, the nonword neighbor primes and targets shared morphemic representations in addition to orthographic representations, the nonword neighbor priming effect in these experiments is likely to have been due mainly to morphemic overlap.

Note also that the facilitory priming effect from the nonword neighbor primes was limited to the low-frequency targets in Experiment 3. In contrast, Davis and Lupker

(2006) reported evidence of facilitory priming effects from nonword neighbor primes for both high- and low-frequency targets. This difference may also reflect different loci of the nonword neighbor priming effects in the two situations (i.e., orthographic vs. morphemic). At the same time, however, there could be an alternative explanation for this frequency difference. As can be seen in Tables 8 and 10, lexical decision responses were quite fast and very accurate for the high-frequency targets. Therefore, the lack of an effect with the high-frequency targets may actually be due to a floor effect.

Relative Prime-Target Frequency and Lexical Competition in Kanji Neighbor Priming

The present results appear to be most consistent with the idea that inhibitory effects at the lexical level are counteracted by morphemic (and orthographic) facilitation. However, with regard to the effect of relative prime-target frequency, the data in the experiments in Chapter 3 were somewhat different from the results reported in recent masked priming studies using English and Japanese Katakana words (Nakayama et al., 2008 and Experiments 1 and 2 in Chapter 2). In those studies, when words had many neighbors, strong inhibition effects from neighbor primes were observed regardless of prime-target frequency. As previously noted, Nakayama et al. (2008) showed that for words with many neighbors (e.g., $M = 10$), inhibition effects were statistically equivalent for low-frequency targets primed by high-frequency neighbors and for high-frequency targets primed by low-frequency neighbors. In contrast, when words have few neighbors (e.g., *M* = 2.7), inhibition effects were found only for low-frequency targets primed by high-frequency neighbors, consistent with the original assumptions of activation-based models. The significant inhibition for high-frequency targets primed by low-frequency neighbors was interpreted as implying that when words have many neighbors, even a low-frequency neighbor prime is an effective inhibitor because it activates a large number of neighbors which then collectively compete with the target.

In the experiments in Chapter 3, the stimuli certainly had many neighbors (e.g., *M* > 220; also see Footnote 12). However, the data suggest that, even with all those neighbors, lexical competition actually does not play much of a role for low-frequency prime and high-frequency target pairs. The reasoning is that: 1) inExperiment 3, for these pairs, there was no effect in the latency data and the inhibitory priming effect in the error data was essentially nonexistent (a 1.0% effect for high-frequency targets in comparison to the 5.2% effect for low-frequency targets) with the same being true in Experiment 4 (0.5% vs. 5.4%), and 2) at the same time, in Experiment 5 there was no evidence of a facilitation for high-frequency targets from nonword primes (although the lack of a facilitation effect for high-frequency targets may have been a floor effect, as noted above). That is, for high-frequency targets primed by low-frequency neighbors, the argument that the null priming effects reflect contrasting effects from facilitory morphemic and inhibitory lexical processing does not seem to follow, because there does not seem to have been any facilitation for these targets in the first place. Therefore, these results seem to suggest that low-frequency neighbors do not have any ability to affect high-frequency targets, even if the words have many neighbors.

A possible explanation of why the present results may have been different from those of Nakayama et al. (2008) may be related to the fact that Kanji compound primes must go through a morphemic decomposition process before the whole-word representation is fully activated (e.g., Taft, 2003; 2004), a process that would obviously require some minimum amount of time to complete. For English and Katakana words, the presentation of low-frequency primes may co-active their neighbors more rapidly, producing more rapid competition with high-frequency targets. For Kanji compounds , however, the co-activation of the prime's neighbors and, hence, their ability to compete may grow somewhat more slowly since the primes must first be analyzed morphemically. Indeed, one could even argue that this mandatory decomposition process, with the associated slowdown in the activation of neighbors, may explain why the competition process appears to be weaker overall in Kanji than in alphabetic languages like English and in Katakana.

Differences between the Present Results and Zhou et al.'s (1999) Results

The fact that word neighbor primes produced a small inhibitory priming effect in the experiments in Chapter 3 (although only on error rates) means that these data contrast sharply with those of Zhou et al. (1999). Zhou et al. repeatedly observed large facilitory priming effects even when the common character in the prime and target denoted different senses (e.g., 华桥, "overseas Chinese" – 华贵, "luxurious"). As the present investigation was not an investigation of the contrast between Chinese and Kanji, I can only speculate as to the reason for this difference. One possibility is that the relative frequencies of the primes and targets are a crucial factor that was not taken into account in Zhou et al.'s experiments. As noted, the prime frequencies were somewhat lower than the target frequencies in Zhou et al.'s experiments, which would have made it quite difficult to produce an inhibitory priming effect. In contrast, in the present experiments, when the relative frequencies of primes and targets were manipulated, the inhibition patterns were clearer when the prime frequencies were higher than the target frequencies, with there being little evidence of inhibition (or facilitation) for low-frequency prime and high-frequency target pairs. A proper comparison of neighbor priming effects for Chinese and Japanese Kanji compounds would require a manipulation of relative prime and target frequency in Chinese.

It should also be noted that the neighbor pairs used in the present experiments and those used in Zhou et al.'s (1999) experiments could have been different in terms of their semantic relatedness at the whole-word level. That is, for their research purpose, Zhou et al. selected two types of neighbor pairs; the shared constituent character either denoted the same meaning in the prime and target or not. They did not control the whole-word level semantic relatedness of neighbor prime-target pairs and unrelated prime-target pairs for each type of neighbors. They reported the whole-word level semantic relatedness rating for one type of the prime-target pairs, however. For neighbor pairs where the shared constituent denoted the same meaning, semantic relatedness ratings at the whole-word level were very high (see Footenote 9).

On the other hand, in the present study, the stimuli were selected so that prime-target pairs (both neighbor pairs and unrelated pairs) did not have high semantic relatedness at the whole-word level, and that was irrespective of the meaning of the shared character in the prime and target. Therefore the possibility remains that a difference between the results of the present research and those of Zhou et al, (1999) could also have been partially due to different degrees of semantic relatedness at the whole-word level.

What is also possible is that this difference could be based on phonology. That is, given that Zhou et al.'s (1999) facilitory neighbor priming effect for Chinese compounds was modulated by phonological similarity of the common character in the prime and target, whereas the contrast between Experiments 3 and 4 indicates that phonological similarity was of no importance in Kanji neighbor priming, it seems possible that at least some of the difference between our results and those of Zhou et al. reflects differences in the nature of phonological processing for Chinese versus Japanese Kanji words. Clearly, additional research will be required to fully delineate both why the patterns were different in the two sets of experiments and, more generally, the nature of any overall processing differences for Chinese and Japanese Kanji compounds.

Conclusions

Localist activation-based models assume that lexical competition is a fundamental process in visual word recognition. Consistent with this assumption, researchers have documented an inhibitory neighbor priming effect in masked priming studies using a variety of alphabetic languages (e.g., Brysbaert et al., 2000; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995; Nakayama et al., 2008; Segui & Grainger, 1990). The primary purpose of the present experiments was to determine if lexical competition also arises when reading Japanese compounds printed in Kanji, a logographic script. Four lexical decision experiments were conducted with masked neighbor primes using Kanji compounds. In these experiments, neighbor primes had a significant inhibitory effect on error rates, although not on response latencies. Nonword neighbor primes, in contrast, produced a significant facilitory priming effect on both response latencies and errors. In addition, significant inhibition on error rates (and a null effect on the response latencies) to word targets turned into significant facilitation on both response latencies and errors when the same targets were primed by their constituent characters (i.e., a morphemic prime in Experiment 7). Taken together, the results support the conclusion that there is a lexical competition process involved in reading Kanji that is analogous to the one observed in alphabetic languages. A key difference with Kanji neighbor priming, however, is that inhibition due to lexical competition is counteracted by a facilitory priming effect at the morphemic (and, potentially, orthographic) level. One goal for future research will be to more precisely delineate the interplay between inhibitory and facilitory processes in the reading of Kanji compounds.

Chapter 4:Summary and Conclusions of the Present Study

Previous masked priming studies in alphabetic languages (e.g., French, Dutch, Spanish, and English)found that in a lexical decision task, targets primed by their orthographic neighborswere responded to significantly slower and less accurately than when the same targets were primed by unrelated words (e.g., Brysbaert, Lange, & Van Wijnendaele, 2000; Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; Drews & Zwitserlood, 1995; De Moor & Brysbaert, 2000; Duñabeitia, Janack, Pasizzo, & Feldman, 2004; Nakayama, Sears, & Lupker, 2008; Perea, & Carreiras, 2009; Segui & Graigner, 1990) . This phenomenon is termed the inhibitory neighbor priming effect. On the other hand, targets primed by nonword neighbors typically do not produce such an effect; a typical finding is that nonword neighbor primes (especially when the stimuli have few neighbors) facilitate, rather than inhibit target processing (e.g., Davis & Lupker, 2006; Forster, 1987; Forster et al., 1987).

The presence of significant inhibitory neighbor priming effectshas been taken as evidence of lexical competition, a core assumption of activation-based models of visual word recognition (Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). According to activation-based models, lexical competition occurs among activated lexical representations of orthographic neighbors before a word is successfully identified. The absence of inhibition effects from nonword neighbor primes, thus, indicates that the inhibitory neighbor priming effect is indeed due to the processing at the lexical level. Nonword neighbor primes do not have lexical-level representations so they do not produce inhibition effects.

Although inhibitory orthographic neighbor priming effects have been reliably observed in many previous studies in alphabetic languages (e.g., Brysbaert, Lange, & Van Wijnendaele, 2000; Carreiras & Duñabeitia, 2009; Davis & Lupker, 2006; Drews & Zwitserlood, 1995; De Moor & Brysbaert, 2000; Duñabeitia, Janack, Pasizzo, & Feldman, 2004; Nakayama, Sears, & Lupker, 2008; Perea, & Carreiras, 2009; Segui & Graigner, 1990), no study had tested the assumption of lexical competitionusing words that are not based on alphabetic scripts. Therefore, previous research did not provide information on whether lexical competition is specific to visual word recognition process of alphabetic words or whether lexical competition applies tonon-alphabetic words as well.Testing the lexical competition assumption with a non-alphabetic language is important because it gives insight as to whether lexical competition is universal irrespective of apparent differences in orthographic characteristics between alphabetic and non-alphabetic languages.

Equally important was that in the present study, predictions of two major models of visual word recognition were tested. That is, the orthographic neighbor priming effect could only beadequately explained by activation-based models that assume local representations of words(Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). PDP-type models (Seidenberg & McClelland, 1989; Plaut, McClelland, Seidenberg, & Patterson, 1996) do not assume localized word-level representations and do not predict significant inhibitory priming effects from word neighbors. Instead, PDP models predict similar facilitory priming effects from word and nonword neighbor primes.

In the present study, therefore, I attempted to investigate whether inhibitory neighbor priming effects arise with Japanese Katakana and Kanji words. In Chapter 2, Katakana words were tested in three experiments (Experiment 1A, 1B, and 2) and in Chapter 3, Kanji words were tested in five experiments(Experiment 3, 4, 5, 6, and 7). The general predictions of the current investigation were that, if lexical competition is relevant in the visual word recognition process of Katakana and Kanji words, then the responses to targets would be significantly slower when they were preceded by orthographic neighbor primes than when they were preceded by unrelated primes. At the same time, no such effects would be observed when the targets were preceded by nonword orthographic neighbors, again, relative to unrelated nonword primes. The summary of the results of these seven experiments is listed in Table 17.

Table 17. Summary of Results of Present Experiments

Chapter/Exp. #	Script Type/Lexicality	Prime-Target Frequencies	Priming (RT)		Priming (ER)
Chap. 2 / Exp. 1A	Katakana Word	High-Low (センター - セーター)	- 17		- 7.5
		Low-High (セーター - セーター)	- 10		- 1.9
Chap. 2 / Exp. 1B	Katakana Nonword	NW-Low (セルター - セーター)	+ 6		- 2.1
		NW-High (セルター - センター)	0		- 2.3
Chap. 2 / Exp. 2	Katakana Word	High-Low (サービス - サーカス)	- 28		- 9.7
	Katakana Nonword	NW-low (サーロス - サーカス)	+ 6		- 7.1
Chap. 3/ Exp. 3	Kanji Word	High-Low (選手 - 助手)	3		- 5.2
		Low-High (助手 - 選手)	1		- 1.0
Chap. 3/ Exp. 4	Kanji Word	High-Low (選手 - 相手)	3		- 5.6
		Low-High (相手 - 助手)	1		- 0.5
Chap. 3/ Exp. 5	Kanji Nonword	NW-Low (鉄手 - 助手)	+ 30		- 0.7
		NW-High (鉄手 - 選手)	0		- 0.2
Chap. 3/ Exp. 6	Kanji Word	High-Low (支持 - 支障)	-3		- 5.4
	Kanji Nonword	NW-Low (支楽 - 支障)	+ 20		+ 2.9
Chap. 3/ Exp. 7	Kanji Character	(-) -Low (支 - 支障)	+ 31		+ 5.1

Note. A priming effect is obtained by subtracting the mean response values (RT and Errors) for the unrelated prime condition from those for the experimental condition. A positive sign expresses facilitation, whereas a negative sign expresses inhibition.

Lexical Competition and Katakana words

Results from three experiments with Katakana stimuli (in Chapter 2) were very straightforward. As can be seen in Table 17, with Katakana words, clear inhibition effects were observed from word neighbor primes (Experiment 1A and 3). Lexical decisions were significantly slower and more error prone when the targets were primed by orthographic neighbors than when the same targets were primed by unrelated words. The results of Experiment 1A also revealed that relative prime-target frequency was not critical in producing the inhibition effects with Katakana words (that had many neighbors). The data on relative frequency was consistent with my previous study using English stimuli (Nakayama et al., 2008). Priming effects were also significantly modulated by the lexicality of the primes; in the analyses of response latencies, the significant inhibition from word neighbor primes (Experiment 1A and 3) turned into null effects when the same targets were primed by nonword neighbors(Expriment 1B and 3). Such results confirm that the significant inhibition priming effects are at the lexical level.

Note also that because the identical results were observed across two different sets of stimuli (i.e., in Experiments 1A, 1B, and 2), these results should be quite reliable. In addition, these results were essentially the same as those observed in the previous masked priming studies in alphabetic languages. Consequently, these results strongly suggest that lexical competition applies to visual word recognition of Japanese Katakana words.

Lexical Competition and Kanji words

Results from five experiments using Kanji stimuli (in Chapter 3) were more complicated than those using Katakana stimuli (see Table 17). Overall, word neighbors significantly inhibited target processing (in Experiments 3, 4, and 6) but the effects were confined to error rates, and to lower-frequency targets primed by higher-frequency primes. On the other hand, nonword neighbor primes significantly facilitated target processing on response latencies, but the effects were, again, confined to low-frequency targets (in Experiments 5 and 6). For Kanji neighbor priming, it was expected that an inhibition effects at the whole-word level, if it existed, would be counteracted by morphological facilitation by the shared character for Kanji neighbor prime-target pairs. Experiment 7 tested the morphological facilitation component directly and showed that morphological facilitationoccurs during the visual word recognition of Kanji words.

For low-frequency targets, therefore, the results of the experiments are consistent with the interpretation that lexical competition does exist when reading Kanji compounds. That is, the significant inhibition effects were observed forerror rates across three different sets of stimuli (in Experiments 3, 4, and 6), suggesting that the effects were highly reliable. In addition, although word neighbor primes did not significantly slow down target processing, the data patterns (null effects) on response latencies were nevertheless significantly different from the data patterns obtained from nonword neighbor primes and also from single Kanji primes (facilitory effects). These contrasting data patterns clearly show that the facilitation effects from shared Kanji characters, that were due to morphemic overlap between the prime and target, diminished the inhibitory priming effect when the primes were Kanji word neighbors of the targets.

As such, for low-frequency Kanji words, the interpretation that is most consistent with the observed results is that lexical competition does exist in the recognition of Kanji words. Unlike the situations in Katakana, however, the effects in Kanjiwere not as robust as one would wish, because the shared Kanji character produced sizable facilitation that counteracted the lexical inhibition at the whole-word level.

For high-frequency Kanji word targets, however, neither word neighbor primes nor nonword neighbor primes produced observable effects. At present, one cannot offer a clear explanation as to why relative prime-target frequencies play a critical role in lexical competition of Kanji compounds, but unlike the cases with Katakana or English words. Future studies should investigate the effect of relative prime-target frequencies to better understand the nature of lexical competition in the reading of Kanji words.

Activation-Based Models Versus PDP-Type Models of Visual Word Recognition

Another important aspect of the current investigation was to evaluate models of visual word recognition. According to activation-based models (Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981), lexical-level representations in the mental lexiconactively compete with one another when they are partially activated. On the other hand, PDP-type models (e.g., Seidenberg & McClelland, 1989; Plaut et al., 1996) do not assume local representational units that correspond to words. Instead, PDP models assume that a word is represented by a pattern of activation over units representing orthographic, phonological, and semantic features. Therefore, the most straightforward prediction of PDP-type models is that both word and nonword neighbor primes would facilitate target processing relative to unrelated primes, because, regardless of lexicality, neighbor primes share orthographic and phonological features with their targets. In addition, PDP-type models do not expect priming effects to be modulated by prime lexicality since they do not assume active inhibition effects at the lexical level.

The main findings of the present study, that word neighbor primes significantly inhibit lexical decision performance to targets and that word and nonword neighbor primes produce different patterns of priming effects, are more consistent with activation-based models. At the same time, these data cannot be readily explained by the PDP-type models, and, hence, the results of present study provide a challenge to the PDP-type models. Apparently, modifications would be necessary for PDP-type models to accommodate these data.

Concluding Remarks

The results of the current investigation suggest that lexical competition is applicable to the recognition of words employing non-Roman scripts. The data in the present study indicate that lexical competition exists not only when reading Katakana words but also when reading Kanji words, that have very different lexical characteristics from words in alphabetic languages. These datafurther point to the possibility that lexical competition is not limited to a specific type of words in certain languages, but rather, is a universal process that occurs in the visual word recognition of many other languages.At this point, however, these assumptions are overstatements, until further research examines different scripts anddifferent languages. The present investigation is an important first step in better understanding the basic nature of visual word recognition across many different languages.

References

Amano, N., & Kondo, H. (2000).*Nihongo no Goi Tokusei* [Lexical characteristics of Japaneselanguage]. NTT database series (volume 7, number 2; CD-Rom version). Tokyo: Sanseido.

Andrews, A., & Hersch, J. (2010). Lexical precision in skilled readers: Individual differences in Masked neighbor priming. *Journal of Experimental Psychology: General, 139*, 299-318.

Balota, D. A., Yap, M. J., Cortese, M. J., Hutchison, K. A., Kessler, B., Loftis, B., Neely, J. H., Nelson, D. L., Simpson, G. B., & Treiman, R. (2007).The English Lexicon Project.*Behavior Research Methods*, *39*, 445-459.

Brysbaert, M., Lange, M., & Van Wijnendaele, I. (2000). The effects of age-of-acquisition andfrequency-of-occurrence in visual word recognition: Further evidence from the Dutchlanguage. *European Journal of Cognitive Psychology*, *12*, 65-86.

Carreiras, M., & Perea, M. (2002). Masked priming effects with syllabic neighbors in the lexicaldecision task. Journal of Experimental Psychology: Human Perception and Performance, 28, 1228-1242.

Carreiras, M., & Duñabeitia, J. A. (2009, November). Electrophysiological correlates of masked orthographic priming with high- and low-frequency orthographic neighbors. Presented at the 50th Annual Meeting of the Psychonomic Society, Boston, Massachusetts.

Chen, H-C., Yamauchi, T., Tamaoka, K., & Vaid, J. (2007). Homophonic and semantic priming of Japanese kanji words: A time course study. *Psychonomic Bulletin & Review, 14*, 64-69.

Coltheart, M., Davelaar, E., Jonasson, J. T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), Attention and performance VI (pp. 535-555). Hillsdale, NJ: Erlbaum.

Davis, C. J. (2003).Factors underlying masked priming effects in competitive network models ofvisual word recognition. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 121-170), Hove, England: Psychology Press.

Davis, C. J. (2005). N-Watch: A program for deriving neighborhoodsize and other psycholinguistic statistics. *Behavior Research Methods, 37, 65-70.*

Davis, C. J., & Lupker, S. J. (2006).Masked inhibitory priming in English: Evidence for lexicalinhibition.*Journal of Experimental Psychology: Human Perception and Performance, 32*, 668-687.

Davis, C. J., Perea, M., Acha, J. (2009).Re(de)fining the orthographic neighborhood: The role of addition and deletion neighbors in lexical decision and reading. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 1550-1570.

De Moor, W., & Brysbaert, M. (2000). Neighborhood-frequency effects when primes and targetsare of different lengths. *Psychological Research, 63*, 159-162.

Drews, E., & Zwitserlood, P. (1995).Morphological and orthographic similarity in visual wordrecognition.*Journal of Experimental Psychology: Human Perception and Performance*, *21*, 1098-1116.

Duñabeitia, J. A., Itziar, L., Perea, M., & Carreiras, M. (2008). Is Milkman a superhero like Batman? Constituent morphological priming in compound words.*The European Journal of Cognitive Psychology*, *21,* 615-640.

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2009). There is no clam with coats in the calmcoast: Delimiting the transposed-letter priming effect. *The Quarterly Journal of Experimental Psychology*, *62*, 1930-1947.

Feldman, L. B., O'Connor, P. A., & Del Prado Martin, F. M. (2009). Early morphological processing is morpho-semantic and not simply morpho-orthographic: A violation of form-then-meaning accounts of word recognition. *Psychonomic Bulletin & Review*, *16*, 684-691.

Ferrand, L. (1996). The masked repetition priming effect dissipates when increasing the inter-stimulus interval: Evidence from word naming. *Acta Psychologia, 91,* 15-25.

Fiorentino, R., & Fund-Reznicek, E. (2009).Masked morphological priming of compoundconstituents.*The Mental Lexicon, 4,* 159-193.

Forster, K. I. (1987). Form-priming with masked primes: The best-match hypothesis. In M. Coltheart (Ed.), Attention and performance XII (pp. 127-146). Hillsdale, N.J.: Erlbaum.

Forster, K. I., & Davis, C. (1984).Repetition priming and frequency attenuation in lexical access.*Journal of Experimental Psychology: Learning, Memory, and Cognition, 4,* 680-698.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming withgraphemically related forms: Repetition or partial activation? *The Quarterly Journal ofExperimental Psychology*, *39A*, 211-251.

Forster, K. I., & Forster, J. C. (2003). DMDX: A Windows display program with millisecondaccuracy. *Behavior Research Methods, Instruments, & Computers*, *35*, 116-124.

Forster, K. I., & Veres, C. (1998). The prime lexicality effect: Form priming as a function ofprime awareness, lexical status, and discrimination difficulty. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*, 498-514.

Frost, R. (2003). The robustness of phonological effects in fast priming.In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 173-191), Hove, England: Psychology Press.

Fushimi, T., Ijuin, M., Patterson, K., & Tatsumi, I. F. (1999).Consistency,frequency, and lexicality effects in naming Japanese kanji.*Journal of Experimental Psychology: Human Perception & Performance,25*, 382-407.

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: Amultiple read-out model. *Psychological Review*, *103*, 518-565.

Hino, Y., & Lupker, S. J. (1998). The effects of word frequency for Japanese kana and kanjiwords in naming and lexical decision: Can the dual-route model save the lexical-selectionaccount? *Journal of Experimental Psychology: Human Perception and Performance*, *24*, 1431-1453.

Hino, Y., Miyamura, S., & Lupker, S. J. (2011). The nature of orthographic-phonological and orthographic-semantic relationships for Japanese Kana and Kanji words.*Behavior Research Methods,43,* 1110-1151.

Hirose, H. (1992).Kanji no ninchi katei nikansuru kenkyu – puraimingu hou niyoru kentou. [Cognitive processes on the recognition of Kanji – An investigation with a priming paradigm], *Shinrigaku Kenkyu, 63,*303-309.

Huang, H. W., Lee, C, Y., Tsai, J. L., Lee, C. L., Hung, D. L., Tzeng, O. J. (2006). Orthographic neighborhood effects in reading Chinese two-character words. *Neuroreport, 17*, 1061-1065.

Humphreys, G. W., Besner, D., & Quinlan, P. T. (1988).Event perception and the word repetition effect.*Journal of Experimental Psychology: General, 117,* 51-67.

Janack, T., Pastizzo, M. J., & Feldman, L. B. (2004).When orthographic neighbors fail tofacilitate.*Brain and Language*, *90*, 441-452.

Kawakami, M. (2002). Kanji niji-jukugo no ruijigo suu to kousei moji no syutsugen hindo ga goihandan kadai ni oyobosu kouka. [Effects of neighborhood size and character frequency on lexical decisions to two-character Kanji compound words]. *Shinrigaku Kenkyu*, *73*, 346-351.

Kinoshita, S., & Lupker, S. J. (2003).*Masked priming: The state of the art*. Hove, England: Psychology Press.

Marslen-Wilson, W. D., Bozic, M., & Randall, B. (2008). Early decomposition in visual word recognition: Dissociating morphology, form, and meaning. *Language and Cognitive Processes, 23,* 394-421.

McClelland, J.L., & Rumelhart, D. E. (1981). An interactive activation model of context effectsin letter perception: Part 1. An account of basic findings.*Psychological Review*,*88*,375-407.

Nakayama, M., Sears, C. R., & Lupker, S. J. (2008). Masked priming with orthographicneighbors: A test of the lexical competition assumption. *Journal of Experimental Psychology: Human Perception and Performance*, *34*, 1236-1260.

Nakayama, M., Sears, C. R., & Lupker, S. J. (2011). Lexical competition in a non-Roman,syllabic script: An inhibitory neighbor priming effect in Japanese Katakana. *Language and Cognitive Processes*, *26*, 1136-1160.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limitedcapacity attention. *Journal of Experimental Psychology: General*, *106*, 226-254.

Orfanidou, E., Davis, M.H., & Marslen-Wilson, W.D. (2011). Effects of orthographic and semantic opacity in masked and delayed priming: Evidence from Greek. *Language and Cognitive Processes*, *26*, 530-557.

Perea, M., & Lupker, S. J. (2003). Transposed-letter confusability effects in masked form priming. In S. Kinoshita & S. J. Lupker (Eds.), Masked priming: The start of the art (pp. 97-120). New York: Psychology Press.

Perea, M., & Lupker, S. J. (2004). Can caniso prime casino? Transposed letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language, 51,* 231-246.

Perea, M., & Pérez, E. (2009). Beyond alphabetic orthographies: The role of form and phonology in transposition effects in Katakana. *Language and Cognitive Processes, 24,* 67-88.

Perea, M., & Rosa, E. (2000). Repetition and form priming interact with neighborhood density at a brief stimulus onset asynchrony. *Psychonomic Bulletin & Review*, *7*, 668-677.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normaland impaired reading: Computational principles in quasi-regular domains.*Psychological Review*, *103*, 56-115.

Rastle, K., & Davis, M. H. (2003).Reading morphologically complex words: Some thoughts from masked priming. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 279-305), Hove, England: Psychology Press.

Rastle, K., & Davis, M. H. (2008). Morphological decomposition isbased on the analysis oforthography. *Language and Cognitive Processes*,*23*, 942-971.

Rastle, K., Davis, M., & New, B. (2004). The brothin my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, *11*, 1090-1098.

Seidenberg, M. S., & McClelland, J. L. (1989).A distributed, developmental model of wordrecognition and naming.*Psychological Review*, *96*, 523-568.

Segui, J., & Grainger, J. (1990).Priming word recognition with orthographic neighbors: Effectsof relative prime-target frequency.*Journal of Experimental Psychology: HumanPerception and Performance*, *16*, 65-76.

Shoolman, N., & Andrews, A. (2003). Racehorses, Reindeer, and Sparrows: Using masked priming to investigate morphological influences on compound word identification. In S. Kinoshita & S. J. Lupker (Eds.), *Masked priming: The state of the art* (pp. 241-278), Hove, England: Psychology Press.

Taft, M. (2003).Morphological representation as a correlation between form and meaning. In E.M. H. Assink & D. Sandra (Eds.), *Reading complex words: Cross-language studies* (pp. 113-137). Amsterdam: Kluwer.

Taft, M. (2004). Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology*, *57A*, 745-765.

Taft, M., & Kougious, P. (2004).The processing of morpheme-like units in monomorphemicwords.*Brain and Language*, *90*, 9-16.

Tamaoka, K., & Makioka, S. (2004). Frequency of occurrence for units of phonemes, morae, andsyllables appearing in a lexical corpus of a Japanese newspaper.*Behavior Research Methods, Instruments, & Computers*, *36*, 531-547.

Tsai, J.L., Lee, C.Y., Lin, Y.C., Tzeng, O. J.L., & Hung, D. L. (2006). Neighborhoodsize effects of Chinese words in lexical decision and reading. *Language andLinguistics, 7*,659-675.

Versace R., & Nevers, B. (2003).Word frequency effect on repetition priming as a function ofprime duration and delay between the prime and the target.*British Journal ofPsychology, 94,* 389-408.

Verdonschot, R. G., Heij, &W. L. Schiller, N. O. (2010). Semantic context effects when naming Japanese Kanji, but not Chinese Hanzi. *Cognition, 115,* 512-518.

Verdonschot, R. G., Heij, W. L., Paolieri, D., Zhang, Q., &Schiller, N. O. (2011). Homophonic context effects when naming Japanese Kanji: evidence for processing costs? *The Quarterly Journal of Experimental Psychology, 64, 1836-1849.*

Weeks, B. S., Chen, M. J., & Lin, Y-B. (1998). Differential effects of phonological priming on Chinese characterrecognition, *Reading and Writing: An Interdisciplinary Journal, 10,* 201–222.

Wydell, T.N., Butterworth, B.L. & Patterson, K.E. (1995). The inconsistency of consistency effects in reading.The case of Japanese Kanji.*Journal of Experimental Psychology: Learning, Memory,andCognition*, 21,557–572.

Zhou, X., & Marslen-Wilson, W. (1995). Morphological structure in the Chinese mental lexicon. *Language and Cognitive Processes*, *10*, 545-600.

Zhou, X., & Marslen-Wilson, W. (2000). Lexical representation of compound words: Cross-linguistic evidence. *Psychologia*, *43*, 47-66.

Zhou, X., Marslen-Wilson, W., Taft, M., & Shu, H. (1999). Morphology, orthography, andphonology in reading Chinese compound words. *Language and Cognitive Processes*, *14*, 525-565.

Footnotes

1. Normative frequencies were based on the NTT database (Amano & Kondo, 2000) that provides frequency counts based on a corpus of approximately three hundred million words. The normative frequencies reported here are per million words, created by dividing the reported frequencies by 300.
2. The replaced pairs were テロ - ベロ, ガス - トス, ガット - マット, and スポーツ - スポーク. These pairs were replaced by テロ - ソロ, ガスーキス, セット - マット, and ブランド - ブレンド.
3. The four prime-target pairs listed in Footnote2 were excluded from all analyses due to high error rates (greater than 60% for the prime or the target).
4. Two low-frequency targets (エイド and カーゴ) had high error rates (greater than 60%). These targets were excluded from all analyses to be consistent with the treatment of targets with high error rates in Experiment 1A.
5. Three targets (スパート, ポピー, and インサート) were excluded from all analyses because of high error rates (greater than 60%).
6. In these experiments the primes and targets were always matched for number of characters. Note that matching for number of characters does not necessarily match for number of syllables; in fact, for approximately 35% of the prime-target pairs the prime and target differed in the number of syllables, though in almost all cases (91%) this was a one-syllable difference (e.g., the prime had two syllables and the

target had three). Note that this situation is common in the masked neighbor priming studies using English stimuli (e.g., Davis & Lupker, 2006; Forster, Davis, Schoknecht, & Carter, 1987; Nakayama, Sears, & Lupker, 2008). The post-hoc analyses indicated no differences in the priming effects between the prime-target pairs that differed in the number of syllables and the prime-target pairs that did not differ in the number of syllables.

7. A post-hoc analysis was carried out to determine if the magnitude of the inhibitory priming effect varied significantly depending on position of the replaced character in the neighbor pair. The stimuli were divided into two groups: 1) neighbor pairs where the initial character was replaced (e.g., /re.be.ru/ and /no.be.ru/), and 2) neighbor pairs where another character position was replaced (e.g.,/se.e.ta.a/ and /se.n.ta.a/, and /ke.e.su/ and /ke.e.ki/). For Experiment 1A, the priming effect for low-frequency targets was 29 ms when the initial character was replaced and 20 ms when another character was replaced; for the high-frequency targets the priming effects were 11 ms and 9 ms, respectively. For Experiment 2 the two priming effects were identical (36 ms). These analyses indicate that the magnitude of the priming effect does not change depending on the position of the replaced character in the neighbor pair. This outcome is consistent with results reported by Janack et al. (2004), who found that the size of the inhibition effect from neighbor primes was not

significantly different for neighbor pairs that differed in the initial letter (e.g., “mast-cast”) and neighbor pairs that differed in the last letter (“cash-cast”).

8. When describing the pronunciation of a Kanji compound word using Roman letters, phonetic format from Tamaoka and Makioka (2004) is used.
9. The facilitation effect was significantly larger when the shared character denoted the same meaning in the neighbor prime-target pairs than when the shared character denoted a different meaning. Such difference was likely due to the fact that neighbor prime-target pairs were also highly semantically related at the whole-word level when the shared character denoted the same meaning (e.g., the mean semantic relatedness rating for such type of neighbors was 6.4 in a 9-point scale in Zhou et al.,’s, 1999, study). No semantic relatedness ratings were given for the other type of neighbor pairs, however.
10. In fact, pre-activation of morphological representations of a single character was originallydiscussed by Zhou et al.(1999) as a locus of the facilitory effect observed in their experiments. Zhou et al. explained that the facilitory priming effects from their neighbor primes are a result of a shared constituent character pre-activating multiple morphemic representations (senses) tied to the character. They argued that this pre-activation due to morphology facilitated the identification of compound targets in their masked priming conditions, whether the prime-target pairs were semantically related at the whole word level or not.

11. The NTT database (Amano & Kondo, 2000) provides frequency counts based on a corpus of 287,792,797 words. The normative frequencies reported here are per million words, computed by dividing the original frequencies by 287.79.
12. The number of neighbors was determined using Amano and Kondo’s (2000) normative frequency corpus. Note that this database contains a very large set of words (360,850 words) and thereforethe number of Kanji neighbors reported for stimuli in the present experiments may be a significantoverestimateof the actual numberof neighbors existing in the mental lexicon of average Japanese-speakers. The number of neighborsfor stimuli in other languages is normally computed on a more restricted set of words. For example, the English Lexicon Project (Balota et al., 2007) calculates the number of neighbors based on a 40,481 word corpus (in the restricted lexicon)and the N-watch (Davis, 2005) program does so based on a 30,605 word corpus.
13. Determining the precise meaning of a single Kanji charactercan often be quite difficultbecause many single Kanji characters do not have an unambiguous meaning when they appear in isolation(see Weeks, Chen & Lee, 1998, for a discussion of the analogous situation with single Chinese characters). For the rating task, participants were asked to give a rating of 1 when they were not sure of the precise meaning of a prime.

14. In Experiments 3-6, approximately half of the neighborprime-target pairs share their first character and approximately halfshare their second. To determine whether this factor mattered in those experiments, the priming effects were examined for low-frequency targets primedby high-frequency neighbors as a function of the positionof the shared constituent character. For this analysis, the primingeffects for items in Experiment 3, 4, and 6 were combined toincrease the power of the analysis. The contrast between prime-target pairs withthe shared constituent character in the first ($n = 70$) versusthe second position ($n =71$) showed no interaction betweenpositional overlap and priming, either in the analysis ofresponse latencies, $F_i(1, 139) = 1.42$, $p > .10$, or in the analysis oferrors, $F_i(1, 139) = 1.04$, $p > .10$. In addition, I also analyzed whether thepriming effects were affected by the position of the sharedconstituent character for low-frequency targets primed by nonword neighbors. Forthis analysis, the items in Experiments5 and 6 were combined. Here,again, priming effects were not significantly different for the neighborpairs overlapping in the first ($n = 52$) versus thesecond character position ($n = 50$), as there was no interactionbetween positional overlap and priming, $F_i < 1$, for both response latencies and errors. These results indicate that theposition of the shared constituent character did not affect thepattern of the priming effects to any noticeable degree in those experiments.

Appendix A CHAPTER 2: Critical Stimulus Materials used in Experiment 1A

HF neighbor prime	HF unrelated prime	LF target	LF neighbor prime	LF unrelated prime	HF target
メーカー	スタート	**ビーカー**	ビーカー	スマート	**メーカー**
ホテル	クラス	**ホイル**	ホイル	ケーキ	**ホテル**
ケース	ホテル	**ケーキ**	ケーキ	ポット	**ケース**
スタート	メーカー	**スマート**	スマート	ビーカー	**スタート**
ホール	ビデオ	**ホース**	ホース	クラゲ	**ホール**
プロ	デモ	**トロ**	トロ	デマ	**プロ**
ビデオ	ポスト	**ロデオ**	ロデオ	ホース	**ビデオ**
ポスト	ケース	**ポット**	ポット	ロデオ	**ポスト**
クラス	ホール	**クラゲ**	クラゲ	ホイル	**クラス**
デモ	プロ	**デマ**	デマ	トロ	**デモ**
センター	トラック	**セーター**	セーター	トラップ	**センター**
ドル	テロ	**ヒル**	ヒル	ベロ	**ドル**
トップ	データ	**リップ**	リップ	ゲート	**トップ**
データ	ソフト	**デルタ**	デルタ	リップ	**データ**
コスト	ブーム	**ダスト**	ダスト	ブーケ	**コスト**
テロ	ドル	**ベロ**	ベロ	ヒル	**テロ**
ソフト	ルート	**ソファ**	ソファ	デルタ	**ソフト**
トラック	センター	**トラップ**	トラップ	セーター	**トラック**
ルート	トップ	**ゲート**	ゲート	ソファ	**ルート**
ブーム	コスト	**ブーケ**	ブーケ	ダスト	**ブーム**

アジア	バブル	**アジト**	アジト	カーゴ	**アジア**
サービス	スポーツ	**サーカス**	サーカス	スポーク	**サービス**
ビル	カネ	**ビリ**	ビリ	カス	**ビル**
スポーツ	サービス	**スポーク**	スポーク	サーカス	**スポーツ**
バブル	リーグ	**ダブル**	ダブル	アジト	**バブル**
ニュース	サッカー	**ジュース**	ジュース	ハッカー	**ニュース**
カネ	ビル	**カス**	カス	ビリ	**カネ**
カード	アジア	**カーゴ**	カーゴ	リング	**カード**
リーグ	カード	**リング**	リング	ダブル	**リーグ**
サッカー	ニュース	**ハッカー**	ハッカー	ジュース	**サッカー**
チーム	エイズ	**チーク**	チーク	ノベル	**チーム**
テーマ	ファン	**パーマ**	パーマ	ファー	**テーマ**
コメ	ガス	**コケ**	コケ	トス	**コメ**
レベル	チーム	**ノベル**	ノベル	コーン	**レベル**
エイズ	コース	**エイド**	エイド	チーク	**エイズ**
ファン	テーマ	**ファー**	ファー	パーマ	**ファン**
ガス	コメ	**トス**	トス	コケ	**ガス**
コース	レベル	**コーン**	コーン	エイド	**コース**
ルール	ガット	**ツール**	ツール	マット	**ルール**
ガット	ルール	**マット**	マット	ツール	**ガット**

Appendix BCHAPTER 2: Critical Stimulus Materials used in Experiment 1B

Neighbor prime	Unrelated prime	LF target	HF target
トーカー	スハート	ビーカー	メーカー
ホッル	ケーレ	ホイル	ホテル
ケーレ	ポキト	ケーキ	ケース
スハート	トーカー	スマート	スタート
ホート	クラリ	ホース	ホール
スロ	デム	トロ	プロ
モデオ	ホート	ロデオ	ビデオ
ポキト	モデオ	ポット	ポスト
クラリ	ホッル	クラゲ	クラス
デム	スロ	デマ	デモ
セルター	トラッコ	セーター	センター
レル	ツロ	ヒル	ドル
セップ	ベート	リップ	トップ
デンタ	ソフン	デルタ	データ
アスト	ブーボ	ダスト	コスト
ツロ	レル	ソロ	テロ
ソフン	デンタ	ソファ	ソフト
トラッコ	セルター	トラップ	トラック
ペート	セップ	ゲート	ルート
ブーボ	アスト	ブーケ	ブーム
アジキ	カーレ	アジト	アジア

サールス	ブウンド	サーカス	サービス
ビコ	カハ	ビリ	ビル
ブウンド	サールス	ブレンド	ブランド
モブル	リッグ	ダブル	バブル
ビュース	モッカー	ジュース	ニュース
カハ	ビコ	カス	カネ
カーレ	アジキ	カーゴ	カード
リッグ	モブル	リング	リーグ
モッカー	ビュース	ハッカー	サッカー
チーコ	エイネ	チーク	チーム
セーマ	ファト	パーマ	テーマ
コホ	ビス	コケ	コメ
カベル	チーコ	ノベル	レベル
エイネ	コーヘ	エイド	エイズ
ファト	セーマ	ファー	ファン
ピス	コホ	キス	ガス
コーヘ	カベル	コーン	コース
ジール	クット	ツール	ルール
クット	ジール	マット	セット

Appendix CCHAPTER 2: Critical Stimulus Materials used in Experiment 2

Word neighbor prime	Word unrelated prime	Nonword neighbor prime	Nonword unrelated prime	Target
アジア	パイプ	アジク	ソイプ	アジト
シェア	モデル	シゲア	モフル	シニア
モデル	シェア	モフル	シゲア	モラル
パイプ	アジア	ソイプ	アジク	レイプ
シリーズ	サミット	シゴーズ	ケミット	シューズ
アパート	サービス	クパート	サーロス	スパート
イメージ	サッカー	ルメージ	テッカー	ダメージ
スタイル	ポイント	スヘイル	コイント	スマイル
ストップ	ライバル	スボップ	ライール	スキップ
ポスター	ストップ	デスター	スボップ	シスター
ポイント	スタイル	コイント	スヘイル	ペイント
ライバル	アパート	ライール	クパート	ライフル
サービス	イメージ	サーロス	ルメージ	サーカス
サッカー	シリーズ	テッカー	シゴーズ	ロッカー
サミット	ポスター	ケミット	デスター	リミット
クラブ	ピアノ	クラホ	ピアク	クラゲ
ソフト	レベル	ソフコ	メベル	ソファ
レベル	ソフト	メベル	ソフコ	ラベル
ピアノ	クラブ	ピアク	クラホ	ピアス
コンサート	パーティー	ベンサート	レーティー	インサート

パーティー	コンサート	レーティー	ベンサート	**ダーティー**
スーパー	トラック	シーパー	トラモク	**ペーパー**
スタート	センター	スホート	センモー	**スカート**
スピード	タクシー	スコード	ヅクシー	**スペード**
センター	チェック	センモー	チョック	**センサー**
タクシー	スピード	ヅクシー	スコード	**セクシー**
チェック	スーパー	チョック	シーパー	**チャック**
トラック	ニュース	トラモク	フュース	**トランク**
トラブル	スタート	トラケル	スホート	**トラベル**
ニュース	トラブル	フュース	トラケル	**ジュース**
ゲリラ	バブル	キリラ	バキル	**ゴリラ**
バブル	ゲリラ	バキル	キリラ	**バジル**
コピー	マニラ	セピー	トニラ	**ポピー**
マニラ	コピー	トニラ	セピー	**バニラ**
マンション	プログラム	オンション	ニログラム	**テンション**
プログラム	マンション	ニログラム	オンション	**キログラム**
フランス	ショック	フレンス	ショッロ	**フェンス**
マイナス	シーズン	マイナポ	モーズン	**マイナー**
メーカー	キューバ	ソーカー	キュール	**ポーカー**
メンバー	オープン	ゴンバー	オーキン	**ナンバー**
ラウンド	マイナス	ラウンフ	マイナポ	**ラウンジ**
オープン	フランス	オーキン	フレンス	**オーブン**
キューバ	メーカー	キュール	ソーカー	**キュート**
シーズン	メンバー	モーズン	ゴンバー	**レーズン**

ショック	ラウンド	ショッロ	ラウンフ	**ショップ**
ゴルフ	ホテル	モルフ	ホスル	**ウルフ**
ホテル	ゴルフ	ホスル	モルフ	**ホタル**
スキー	リスク	スキバ	カスク	**スキル**
リスク	スキー	カスク	スキバ	**デスク**
バランス	デパート	バヌンス	デキート	**バカンス**
デパート	バランス	デキート	バヌンス	**デザート**
ブランド	エンジン	ブランハ	ムンジン	**ブランク**
ブロック	コメント	ブキック	アメント	**ブラック**
グループ	リーダー	グソープ	カーダー	**グレープ**
コメント	グループ	アメント	グソープ	**セメント**
リーダー	キャンプ	カーダー	キャリプ	**オーダー**
インフレ	リポート	インフチ	リマート	**インフラ**
エンジン	ブランド	ムンジン	ブランハ	**ニンジン**
キャンプ	インフレ	キャリプ	インフチ	**キャップ**
リポート	ブロック	リマート	ブキック	**リピート**

Appendix DCHAPTER 3: Critical Stimulus Materials used in Experiment 3

High-frequency Primes (Neighbor, Unrelated) and Low-frequency Targets			Low-frequency Primes (Neighbor Unrelated) and High-frequency Targets		
選手	影響	**助手**	助手	反響	**選手**
影響	選手	**反響**	反響	助手	**影響**
反対	以上	**反感**	反感	机上	**反対**
以上	反対	**机上**	机上	反感	**以上**
会談	女性	**会報**	会報	大意	**会談**
大会	会談	**大意**	大意	酸性	**大会**
地域	首相	**地名**	地名	時差	**地域**
時代	地域	**時差**	時差	宰相	**時代**
女性	大会	**酸性**	酸性	会報	**女性**

首相	時代	**宰相**	宰相	地名	**首相**
一部	電話	**一読**	一読	神話	**一部**
電話	一部	**神話**	神話	一読	**電話**
指摘	自宅	**指数**	指数	自供	**指摘**
自宅	指摘	**自供**	自供	指数	**自宅**
意見	生活	**意地**	意地	生還	**意見**
生活	意見	**生還**	生還	意地	**生活**
社長	計画	**家長**	家長	区画	**社長**
計画	社長	**区画**	区画	家長	**計画**
発表	企業	**発着**	発着	学業	**発表**
企業	発表	**学業**	学業	発着	**企業**
言葉	資金	**言霊**	言霊	砂金	**言葉**
資金	言葉	**砂金**	砂金	言霊	**資金**

検討
合意
国内
銀行
組織
事件
代表
全国
協力
制度
国際
内容
結果

核心
家内
合憲
組成
急行
代休
事典
重力
開国
交際
角度
結社
内縁

検問
合憲
家内
急行
組成
事典
代休
開国
重力
角度
交際
内縁
結社

検問
合憲
家内
急行
組成
事典
代休
開国
重力
角度
交際
内縁
結社

中心
国内
合意
組織
銀行
代表
事件
協力
全国
国際
制度
結果
内容

検討
合意
国内
銀行
組織
事件
代表
全国
協力
制度
国際
内容
結果

中心	検討	**核心**	核心	検問	**中心**
教授	年度	**教習**	教習	年号	**教授**
年度	教授	**年号**	年号	教習	**年度**
午前	会社	**最前**	最前	会費	**午前**
会社	午前	**会費**	会費	最前	**会社**

Appendix: ECHAPTER 3: Critical Stimulus Materials used in Experiment 4

High-frequency Primes (Neighbor, Unrelated) and Low-frequency Targets

選手	仕事	**右手**
仕事	選手	**検事**
反対	以上	**反物**
以上	反対	**年上**
会談	女性	**会得**
大会	会談	**大雨**
地域	首相	**地道**
時代	地域	**時折**
女性	大会	**相性**
首相	時代	**手相**

Low-frequency Primes (Neighbor, Unrelated) and High-frequency Targets

右手	検事	**選手**
検事	右手	**仕事**
反物	年上	**反対**
年上	反物	**以上**
会得	大雨	**会談**
大雨	相性	**大会**
地道	時折	**地域**
時折	手相	**時代**
相性	会得	**女性**
手相	地道	**首相**

一部	電話	**一言**	一言	小話	**一部**
電話	一部	**小話**	小話	一言	**電話**
指摘	影響	**指先**	指先	影絵	**指摘**
影響	指摘	**影絵**	影絵	指先	**影響**
意見	生活	**下見**	下見	生粋	**意見**
生活	意見	**生粋**	生粋	下見	**生活**
社長	計画	**気長**	気長	図画	**社長**
計画	社長	**図画**	図画	気長	**計画**
発表	企業	**発作**	発作	仕業	**発表**
企業	発表	**仕業**	仕業	発作	**企業**
言葉	資金	**言動**	言動	針金	**言葉**
資金	言葉	**針金**	針金	言動	**資金**
結果	内容	**結納**	結納	内側	**結果**

内容	結果	**内側**	内側	結納	**内容**
国際	制度	**間際**	間際	支度	**国際**
制度	国際	**支度**	支度	間際	**制度**
協力	全国	**自力**	自力	島国	**協力**
全国	協力	**島国**	島国	自力	**全国**
代表	事件	**代物**	代物	事柄	**代表**
事件	代表	**事柄**	事柄	代物	**事件**
組織	銀行	**組曲**	組曲	修行	**組織**
銀行	組織	**修行**	修行	組曲	**銀行**
国内	合意	**身内**	身内	合間	**国内**
合意	国内	**合間**	合間	身内	**合意**
検討	中心	**仇討**	仇討	真心	**検討**
中心	検討	**真心**	真心	仇討	**中心**

今年
年度
午前
会社

年度
今年
会社
午前

今更
年下
気前
会釈

今更
年下
気前
会釈

年下
今更
会釈
気前

今年
年度
午前
会社

Appendix: FCHAPTER 3: Critical Stimulus Materials used in Experiment 5

Nonword Primes (Neighbor, Unrelated) and Low-frequency Targets

鉄手	犬響	**助手**
犬響	鉄手	**反響**
反蜜	泣上	**反感**
泣上	反蜜	**机上**
会犯	大姪	**会報**
大姪	寅性	**大意**
地客	時橋	**地名**
時橋	魅相	**時差**
寅性	会犯	**酸性**
魅相	地客	**宰相**

Nonword Primes (Neighbor, Unrelated) and High-frequency Targets

鉄手	犬響	**選手**
犬響	鉄手	**影響**
反蜜	泣上	**反対**
泣上	反蜜	**以上**
会犯	大姪	**会談**
大姪	寅性	**大会**
地客	時橋	**地域**
時橋	魅相	**時代**
寅性	会犯	**女性**
魅相	地客	**首相**

一部	時話	一写
電話	一写	時話
指摘	自誠	指本
自宅	指本	自誠
意見	生激	意策
生活	意策	生激
社長	最画	鳥長
計画	鳥長	最画
発表	熱業	発変
企業	発変	熱業
言葉	召金	言子
資金	言子	召金
結果	内火	結度

一読	時話	一写
神話	一写	時話
指数	自誠	指本
自供	指本	自誠
意地	生激	意策
生還	意策	生激
家長	最画	鳥長
区画	鳥長	最画
発着	熱業	発変
学業	発変	熱業
言霊	召金	言子
砂金	言子	召金
結社	内火	結度

内火	結度	**内縁**
石際	菌度	**交際**
菌度	石際	**角度**
犯力	線国	**重力**
線国	犯力	**開国**
代聴	事日	**代行**
事日	代聴	**事典**
組源	度行	**組成**
度行	組源	**急行**
描内	合回	**家内**
合回	描内	**合憲**
検紙	適心	**検問**
適心	検紙	**核心**

内火	結度	**内容**
石際	菌度	**国際**
菌度	石際	**制度**
犯力	線国	**協力**
線国	犯力	**全国**
代聴	事日	**代表**
事日	代聴	**事件**
組源	度行	**組織**
度行	組源	**銀行**
描内	合回	**国内**
合回	描内	**合意**
検紙	適心	**検討**
適心	検紙	**中心**

教卵	年算	**教習**	教卵	年算	**教授**
年算	教卵	**年号**	年算	教卵	**年度**
対前	会林	**最前**	対前	会林	**午前**
会林	対前	**会費**	会林	対前	**会社**

Appendix GCHAPTER 3: Critical Stimulus Materials used in Experiment 6

Word Neighbor Primes, Word Unrelated Primes, Nonword Neighbor Primes, Nonword Unrelated Primes,and Low-frequency targets.

国家	存在	走家	走在	実家
開発	制度	開率	制率	開拓
放送	議論	放本	議本	放火
参加	国民	立加	立民	付加
決定	販売	決人	販人	決闘
全国	予定	全正	予正	全裸
中心	市場	選心	選場	決心
保護	維持	決護	決持	養護
展開	投票	芸開	芸票	満開
国連	統一	入連	入一	常連

期待	選手	号待	号手	**接待**
情報	幹部	情門	幹門	**情緒**
価格	主張	宮格	宮張	**品格**
平均	設置	平隊	設隊	**平年**
交渉	利用	交倒	利倒	**交番**
実施	国内	実来	国来	**実権**
活動	環境	財動	財境	**反動**
対象	結果	対情	結情	**対岸**
説明	電話	店明	店話	**鮮明**
議員	会談	脳員	脳談	**店員**
実現	表明	実活	表活	**実習**
新聞	改正	布聞	布正	**見聞**
午後	一部	様後	様部	**死後**

支持	責任	支楽	責楽	**支障**
改革	会議	改年	会年	**改札**
団体	法案	凶体	凶案	**液体**
判断	監督	判標	監標	**判読**
技術	導入	能術	能入	**学術**
報告	輸入	報有	輸有	**報復**
現在	状況	現死	状死	**現物**
事実	処理	苦実	苦理	**無実**
市民	教育	青民	青育	**漁民**
関連	組織	関隙	組隙	**関脇**
意見	社長	凍見	凍長	**花見**
以上	対応	滴上	滴応	**真上**
連合	政策	愛合	愛策	**歩合**

長官	施設	長母	施母	**長靴**
安定	外交	安減	外減	**安物**
作品	人間	作熱	人熱	**作用**
最高	文化	氏高	氏化	**残高**
時間	外相	目間	目相	**世間**
経営	自宅	経乾	自乾	**経典**
予定	事業	獲定	獲業	**勘定**
野党	今後	野段	今段	**野原**
政治	今年	麻治	麻年	**全治**
生活	建設	生料	建料	**生首**
国際	姿勢	家際	家勢	**窓際**
内容	今回	内質	今質	**内訳**
合意	資金	合黒	資黒	**合宿**

強調	拡大	強里	拡里	**強火**
指摘	支援	指約	支約	**指図**
銀行	業界	振行	振界	**修行**
貿易	理由	鳥易	鳥由	**安易**
計画	病院	左画	左院	**版画**
平和	言葉	平源	言源	**平手**
子供	全体	入供	入体	**自供**
今年	検討	壁年	壁討	**享年**
反対	仕事	反兵	仕兵	**反吐**
提案	調査	提神	調神	**提灯**
商品	行政	暑品	厚政	**手品**
海外	写真	海着	写着	**海辺**
立場	事故	区場	区故	**劇場**

輸出	被告	位出	位告	**家出**
背景	地方	背養	地養	**背骨**

Appendix HCHAPTER 3: Critical Stimulus Materials used in Experiment 7

Morphological Primes, Unrelated Primes, and Low-frequency Targets

家	取	実家
開	集	開拓
放	革	放火
加	区	付加
決	五	決闘
全	氏	全裸
心	午	決心
護	疑	養護
開	法	満開
連	調	常連
待	害	接待
情	利	情緒
格	研	品格
平	言	平年
交	先	交番
実	最	実権

動	理	反動
対	円	対岸
明	所	鮮明
員	前	店員
実	米	実習
聞	演	見聞
後	新	死後
支	引	支障
改	空	改札
体	運	液体
判	府	判読
術	起	学術
報	局	報復
現	要	現物
実	表	無実
民	力	漁民
芝	十	芝居
見	京	花見

上	入	真上
合	田	歩合
長	政	長靴
安	参	安物
作	教	作用
高	通	残高
間	東	世間
経	資	経典
定	部	勘定
野	数	野原
治	共	全治
生	代	生首
際	使	窓際
内	手	内訳
合	市	合宿
強	戦	強火
指	原	指図
行	金	修行

易	構	安易
画	計	版画
平	考	平手
供	英	自供
年	日	享年
反	千	反吐
提	語	提灯
品	点	手品
海	役	海辺
場	的	劇場
出	事	家出
背	因	背骨