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Do Masked Orthographic Neighbor Primes Facilitate or Inhibit the Processing of Kanji Compound Words?

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In the masked priming paradigm, when a word target is primed by a higher frequency neighbor (e.g., blue–BLUR), lexical decision latencies are slower than when the same word is primed by an unrelated word of equivalent frequency (e.g., care–BLUR). This inhibitory neighbor priming effect (e.g., Davis & Lupker, 2006; Segui & Grainger, 1990) is taken as evidence for the lexical competition process that is an important component of localist activation-based models of visual word recognition (Davis, 2003; Grainger & Jacobs, 1996; McClelland & Rumelhart, 1981). The present research looked for evidence of an inhibitory neighbor priming effect using words written in Japanese Kanji, a logographic, nonalphabetic script. In 4 experiments (Experiments 1A, 1B, 3A, and 3B), inhibitory neighbor priming effects were observed for low-frequency targets primed by higher frequency Kanji word neighbors (情報-情緒). In contrast, there was a significant facilitation effect when targets were primed by Kanji nonword neighbors (情門-情緒; Experiments 2 and 3). Significant facilitation was also observed when targets were primed by single constituent Kanji characters (情-情緒; Experiment 4). Taken together, these results suggest that lexical competition plays a role in the recognition of Kanji words, just as it does for words in alphabetic languages. However, in Kanji, and likely in other logographic languages, the effect of lexical competition appears to be counteracted by facilitory morphological priming due to the repetition of a morphological unit in the prime and target (i.e., in Kanji, each character represents a morpheme).

Keywords: masked priming, orthographic neighbors, lexical competition, Kanji script, inhibitory neighbor priming

Language researchers have used a wide variety of experimental paradigms to explore and understand the processes involved in skilled reading. Of the paradigms used to study the visual word identification process, the masked priming paradigm has proven to be one of the more useful tools available to researchers. 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. Participants respond to the target, typically by making a speeded lexical decision (for a review, see Kinoshita & Lupker, 2003). Because the prime word is presented briefly and masked by both the forward mask and the target, participants are seldom aware of its existence, much less its identity, and therefore, its impact on target processing can be assessed in the absence of any conscious prime processing. Another major advantage of the masked priming paradigm is that the same stimuli are responded to in different experimental conditions; for example, in form priming experiments, responses to the same target word (e.g., FATE) are measured after having been primed by a formally similar word (e.g., fade) and by a word that is not formally similar (e.g., slim). Because differences in response latencies to the same target are the basis of any effect, there are no concerns about uncontrolled stimulus differences between experimental conditions.

The masked priming paradigm has been an especially important tool for studying the lexical competition principle incorporated into most localist activation-based models of visual word identification, such as the interactive-activation model (McClelland & Rumelhart, 1981), the multiple read-out model (Grainger & Jacobs, 1996), and other more recent models (e.g., Davis, 2003). Specifically, these models assume that the lexical representation of a presented word and those of orthographically similar words (the word's "neighbors") are activated simultaneously early in processing, and that, once activated, they compete with one another through a process involving mutual inhibition. The lexical repre-

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sentation of the presented word is assumed to be selected only after the competition has been resolved.

In empirical tests of these models, the definition of orthographic neighbors adopted by Coltheart, Davelaar, Jonasson, and Besner (1977) has typically been used: namely, the words that are created by changing one letter of a target word while maintaining letter positions (e.g., "case," "ease," and "vast" are all orthographic neighbors of "vase"). A number of recent studies suggest that this definition is too narrow and that the lexical units of other visually similar words are also relevant to the process (e.g., Davis, Perea, & Acha, 2009; De Moor & Brysbaert, 2000). Regardless of the exact definition of orthographic neighbors, in all the models, the relative frequencies of the presented word and its neighbors are important in determining how quickly the competition between the word and its neighbors is resolved. The key assumption embodied in these models is that words with higher frequency neighbors experience more intralexical inhibition because higher frequency neighbors are powerful competitors, substantially slowing the accumulation of activation necessary for the word's lexical unit to reach threshold. Words with only lower frequency neighbors, on the other hand, experience much less intralexical competition and, as a consequence, the lexical activation process is largely unaffected by the existence of those neighbors.

Masked Priming Using Word Neighbor Primes

Segui and Grainger (1990) were the first to use the masked priming paradigm to look for evidence of the lexical competition predicted by localist activation-based models. They reasoned that although a prime's presentation would preactivate a number of lexical representations (i.e., representations of the prime and its neighbors), the prime's lexical representation would be the most highly activated. As a result, its ability to compete with a subsequently presented neighbor target would be enhanced. Further, the clearest evidence of the competition process should emerge when the prime is a high-frequency neighbor (e.g., *blue*) of a low-frequency target (e.g., *BLUR*). Therefore, this situation should be most likely to produce an inhibitory priming effect. On the other hand, a low-frequency neighbor prime would not be expected to create much competition with a high-frequency target's processing (e.g., *blur–BLUE*) because the prime will not be a strong competitor even when its lexical representation is preactivated. Consistent with these expectations, Segui and Grainger found that lexical decision latencies were significantly slower when a low-frequency word target was primed by a high-frequency neighbor than when it was primed by an unrelated word (an inhibitory neighbor priming effect), whereas the latencies to high-frequency targets primed by low-frequency neighbors were not significantly different from the latencies to the same targets primed by unrelated primes.

Inhibitory neighbor priming effects have been reported in many languages, including French (Segui & Grainger, 1990), Dutch (Brysbaert, Lange, & Van Wijnendaele, 2000; De Moor & Brysbaert, 2000; Drews & Zwitserlood, 1995), Spanish (Duñabeitia, Perea, & Carreiras, 2009), and English (Andrews & Hersch, 2010; Davis & Lupker, 2006; Janack, Pastizzo, & Feldman, 2004; Nakayama, Sears, & Lupker, 2008). Note, however, that virtually all of the studies that have used the masked neighbor priming paradigm to study inhibitory neighbor priming have used Indo-European languages, where the script used is the Roman alphabet. Recently, however, Nakayama, Sears, and Lupker (2011) reported inhibitory neighbor priming with Japanese Katakana words, a syllabic-based script. Nakayama et al.'s (2011) results do suggest that lexical competition may be a somewhat universal phenomenon.

An additional point that will also be important for the present discussion is that if the neighbor prime is a nonword, the expectation is that lexical competition would be 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, due to the fact that the target's lexical representation would be partially preactivated by the nonword neighbor prime, a prediction that 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). These results indicate that some of the processes engaged by a formally similar prime do facilitate target processing (see Davis, 2003, for a detailed discussion of how these facilitory and inhibitory processes can interact at the lexical level). In addition to the facilitory processes described by Davis (2003), it is also possible that a small amount of facilitation may arise at the letter level (due to the repetition of the letters themselves) and/or at a phonological level (e.g., Frost, 2003). The existence of an inhibition effect from word neighbors, therefore, not only documents the impact of lexical competition, but also indicates that this competition can be a major factor in a masked priming situation, counteracting whatever facilitory processes may also be at work.

Inhibitory Priming Effects in a Logographic Script?

The purpose of the present research was to determine if the concept of lexical competition is also applicable to the processing of logographic scripts, the processing of which appears to be functionally different from that of alphabetic and syllabic scripts. The logographic script used in the present experiments was Japanese Kanji. One aspect of Kanji that is fundamentally different from words written in alphabetic scripts is that each Kanji character is a morpheme. That is, each character has a set of specific meanings associated with it, with its exact meaning depending on the word in which the character appears. For example, the character 日 can mean either "sun," "Japan," or "a day" (e.g., 日照, "*sunshine*"; 日米, "*Japan and America*"; or 日時, "*the date and time*"), among other possibilities. Most Kanji characters also have multiple pronunciations and how a Kanji character is pronounced also depends on the word 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*hoN/, "Japan"), /niti/ when it appears in the word 日米 (/*niti*bei/, "Japan and America") and /hi/ when it appears in the word 日陰 (/*hi*kage/, "shade").[1]

In the present experiments, we used two-character Kanji compound words as stimuli because two-character words represent about 80% of all Kanji words in the Japanese language (e.g., Hino & Lupker, 1998; Hino, Miyamura, & Lupker, 2011) and are therefore reflective of common Japanese vocabulary. We applied the classical definition of orthographic neighbors (Coltheart et al.,

[1] When we describe the pronunciation of a Kanji compound word using Roman letters, we will use the format from Tamaoka and Makioka (2004).

1977) using a Kanji character as the orthographic unit, a definition that was also adopted for previous studies in Japanese (e.g., Fushimi, Ijuin, Patterson, & Tatsumi, 1999; Hino et al., 2011; Hirose, 1992; Kawakami, 2002; Wydell, Butterworth, & Patterson, 1995) and Chinese (e.g., Huang, Lee, Tsai, Lee, Hung, & Tzeng, 2006; Tsai, Lee, Lin, Tzeng, & Hung, 2006). Kanji neighbors, therefore, had one character in common at the same position; for example, 企業 ("enterprise"), 学業 ("schoolwork"), and 仕業 ("an act/handiwork") were considered orthographic neighbors differing at the first character position, and 会議 ("conference"), 会話 ("conversation"), and 会釈 ("nodding/greeting") were considered orthographic neighbors differing at the second character position.

Morphological Considerations

Although our manipulation of orthographic similarity appears straightforward, there is one characteristic of Kanji neighbors that is important to keep in mind. The fact that Kanji neighbors share a constituent character (会議 – 会話) means that they are not only orthographically similar, they are also morphologically related because they would also share a morpheme. Although the shared character does not always denote an identical meaning in each of the neighbor words, which means that Kanji neighbors are not inevitably semantically related, Kanji neighbors are inevitably morphologically related because they share a character that represents the same set of meanings. This aspect of Kanji neighbors means that they are somewhat different from orthographic neighbors in alphabetic languages (e.g., blue–blur), which are only rarely morphologically related (e.g., swim–swam). It also means that a masked Kanji neighbor prime contains an additional potential facilitation component, a component not typically available in the case of masked neighbor priming in alphabetic languages.

As has been demonstrated many times in alphabetic languages, the impact of morphological similarity in masked priming situations is facilitory (e.g., Duñabeitia, Laka, Perea, & Carreiras, 2009; Duñabeitia, 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: Taft & Kougious, 2004). For example, morphological facilitation has been shown to exist regardless of the exact meaning of the shared morpheme represented in a prime and a target: similar priming effects have 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., Järvikivi, Pyykkönen, & Niemi, 2009; see Rastle & Davis, 2008, for a review). These effects are not merely due to the orthographic overlap between the prime and target, but are due to the morphological overlap between them, as prime-target pairs that are not morphologically related, but are merely orthographically related (e.g., brothel–BROTH) do not produce the same level of facilitation. 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 dependent on the position of the matching constituents (first and second constituents prime compound targets equally well) or by the match/mismatch of the meanings of the constituent shared by the prime and target.

Most relevant to the present research, facilitation effects have also been observed for compound word prime-compound word target pairs (e.g., Duñabeitia et al., 2009). Specifically, Duñabeitia, Laka, Perea, and Carreiras, 2009 reported that lexical decisions were significantly facilitated when Basque compound word targets were primed by different compound words that contained the same constituent, with equivalent effects for targets primed by a constituent in the first position (e.g., *book*mark–*BOOK*SHOP) and in the second position (e.g., post*man*–MILK*MAN*). Facilitory priming was also observed when the shared constituent appeared in a different position in the prime and target (e.g., post*man*–*MAN*KIND). Therefore, in the present situation, it seems very likely that there will be facilitory morphological priming with two-character Kanji neighbor primes. As a result, the inhibitory effect of lexical competition, if it exists, will be counteracted to some degree by this facilitation effect due to the morphological overlap between neighbor prime-target pairs, making it more difficult to observe inhibition effects in Kanji than in alphabetic languages.

Masked Neighbor Priming in (Logographic) Chinese

To our 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 compound words. The only similar study was by Zhou, Marslen-Wilson, Taft, and Shu (1999), who used a masked priming procedure with two-character Chinese words as targets. Although the purpose of Zhou et al.'s experiments was not to examine the lexical competition process, and therefore their stimuli were not chosen or manipulated to that end, their experiments did use prime and target pairs that shared the same character in the same position (e.g., 华丽–华贵). Thus, according to the definition of orthographic neighbors adopted here, their experiments were essentially a Chinese version of a neighbor priming study, and their results should therefore offer some insights into the effects of masked neighbor primes on the processing of logographic scripts.

What Zhou et al. (1999) found was that, with masked 57 ms word neighbor primes, there was 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 shared character denoted the same meaning in a prime and target (华丽–华贵, where the shared character meant *splendid*) and also when the shared character denoted different meanings in a prime and target (华桥–华贵, where the shared character meant *Chinese* and *splendid,* respectively), although more priming was observed in the former condition. Zhou et al. also found that these facilitory priming effects were not modulated by the position in which the shared character occurred (the first or second position), consistent with the findings of previous masked morphological priming studies in alphabetic languages (e.g., Duñabeitia et al., 2009; Shoolman & Andrews, 2003). In fact, similar to Duñabeitia et al., there was a facilitation effect even when the shared 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, a facilitation that Zhou et al. suggested was due to morphological overlap. At the same time, the clear facilitation effects Zhou et al. observed provide no evidence that lexical competition at the whole word level plays a role in the processing of logographic words.

Although Zhou et al.'s (1999) results nicely demonstrate the impact of morphological priming in logographic languages, for a number of reasons those results are not particularly informative as to whether lexical competition plays a role in the processing of logographic words. The obvious problem is that, even if there is lexical competition, it will, of course, be difficult to observe its impact against a background of a strong morphological priming effect. As a result, it becomes necessary to consider the impact of other experimental factors, factors that, as noted earlier, were not examined in Zhou et al.'s experiments because those experiments were not designed to test the lexical competition assumption. For example, Zhou et al. did not investigate relative prime-target frequency. Their primes were always lower in frequency than their targets, and, as noted, lower frequency neighbor primes have a very limited ability to inhibit target processing. The contrast between high- and low-frequency primes is a key contrast in investigating the lexical competition assumption. In addition, at least half of the neighbor pairs used by Zhou et al. were highly semantically related at the whole word level. Thus, it's also possible that semantic priming may have further obscured any (negative) impact of lexical competition. For a proper test of the neighbor priming effect, prime-target pairs should not be highly semantically related, as is the case with neighbor pairs in alphabetic languages (e.g., blue—blur). Finally, Zhou et al. did not manipulate the lexicality of the neighbor primes. Their primes were always words. As noted previously, in alphabetic languages, nonword neighbor primes do not produce inhibition effects (e.g., Davis & Lupker, 2006; Forster & Veres, 1998), presumably due to the fact that nonword primes do not strongly activate any particular neighbor of the target. The contrast between priming from word neighbor primes and priming from nonword neighbor primes is, therefore, also a key contrast when investigating the lexical competition assumption. To fully test the hypothesis that lexical competition plays a role in the processing of logographic words then, it is necessary to manipulate relative prime-target frequency and prime lexicality, while keeping the strength of the semantic relationships between primes and targets as weak as possible.

The Present Research

The purpose of the present research was to test the lexical competition assumption with Japanese Kanji orthographic neighbors. To this end, the relative prime-target frequencies of word neighbor pairs were manipulated (Experiment 1A, 1B) and the effect of prime lexicality was examined (Experiment 2, 3A, and 3B). We also directly examined the question of whether there is morphological facilitation in Kanji neighbor priming (Experiment 4). To minimize the impact of semantic priming, only word neighbor prime-target pairs with no obvious semantic relationships were selected.

Our expectations were as follows. If the principles of localist activation-based models are relevant to the processing of Japanese Kanji words, then there would be lexical competition at the whole-word lexical level, in which case Kanji neighbor primes will inhibit target processing. The inhibition effect is unlikely to be as strong as that observed in previous studies with alphabetic languages, however, because of the expected facilitory priming due to the prime and target being morphologically related. Equally important, therefore, is the prediction of localist activation-based models that any inhibition effect should be more evident with high-frequency primes than with low-frequency primes, as well as the prediction that any inhibition effect will be more evident with word primes than with nonword primes.

Experiment 1

Experiment 1 involved an investigation of relative prime-target frequency using Kanji neighbor primes in a masked priming lexical decision task. We also examined the effect of phonological similarity between the neighbor prime-target pairs, a factor that may affect priming effects in Kanji neighbor priming. To do so, we manipulated the degree of phonological overlap between the prime and target: in Experiment 1A, in the neighbor priming condition, the shared constituent character was pronounced the same in the prime and target, whereas in Experiment 1B the shared constituent character was pronounced differently. In addition to being the first masked priming experiments to look for evidence of inhibitory neighbor priming with Kanji script words, these experiments were also the first to examine the effect of phonological similarity on Kanji neighbor priming.

Although it is not clear what effect the phonological properties of the shared constituent characters would have on the recognition of Kanji compound words, Zhou et al. (1999), using Chinese compound words, showed that the phonological properties of the shared constituent characters can influence the pattern of priming effects. In Zhou et al.'s Experiment 4, the impact of morphological similarity was substantially reduced when the shared constituent character was pronounced differently (e.g., 重复(chong[2]fu[4], "repeat") – 重量(zhong[4]liang[4], "weight")). If shared phonology has a similar impact for Kanji compound words, then an inhibition effect from neighbor primes may be easier to detect in Experiment 1B, in which the shared constituent character is pronounced differently in the prime and target.

Method

Participants. The participants were 84 undergraduate students from Waseda University (Tokyo, Japan). All were native speakers of Japanese and reported having normal or corrected-to-normal vision. There were 40 participants in Experiment 1A and 44 in Experiment 1B.

Stimuli. All the stimuli were two-character Kanji words. For each experiment, 40 pairs of orthographic neighbors were selected as the critical stimuli. None of the neighbor pairs appeared to be semantically related at the whole word level as judged by the first author, who is a native Japanese speaker. 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 than the other (using the normative frequencies from the NTT database; Amano & Kondo, 2000). In Experiment 1A, the higher frequency and lower frequency members of the neighbor pair had frequency counts of 277.1 and 3.8 per million words, respectively; in Experiment 1B the corresponding frequency counts were 280.9 and 3.1.[2] All of these words had many orthographic neighbors: the mean number of neighbors was 219.6 for higher frequency targets and 226.3 for lower frequency targets in Experiment 1A, and 225.8 and 258.9 for higher frequency and lower frequency targets in Experiment 1B.[3] For the 40 neighbor pairs used in Experiment 1A, 21 pairs shared a Kanji character in the first character position and 19 pairs shared a Kanji character in the second character position. For the 40 neighbor pairs used in Experiment 1B, 20 pairs shared a Kanji character in the first character position and 20 pairs shared a Kanji character in the second character position.

In Experiment 1A, for the neighbor priming condition, the shared constituent character was pronounced the same in the prime and target (e.g., 選手, /seN*sju*/–助手, /zjosju). In Experiment 1B, for the neighbor priming condition, the shared constituent character was pronounced differently in the prime and target (e.g., 選手, /seN*sju*/–相手, /ai*te*/).

For each experiment, the 40 neighbor pairs were divided into four groups that had similar mean word frequencies. All the pairs within each group were used to create four types of word pairs: (a) high-frequency neighbor prime–low-frequency target (e.g., 選手, "athlete"–助手,"assistant"); (b) high-frequency unrelated prime–low-frequency target (e.g., 影響, "influence"–助手, "assistant"); (c) low-frequency neighbor prime–high-frequency target (e.g., 助手, "assistant"–選手, "athlete"); and (d) low-frequency unrelated prime–high-frequency target (e.g., 反響, "feedback"–選手, "athlete"). Unrelated prime-target pairs were created by reassigning the primes and targets within each 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. 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. The other two groups were used to create the unrelated conditions, one involving high-frequency primes and low-frequency targets and the other involving the reverse assignment. Each participant saw each target (words and nonwords) only once. 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, with one quarter of the participants being presented with each set. The descriptive statistics for the stimuli are listed in Table 1. (The word stimuli used in Experiment 1 are listed in Appendices A and B.)

The same set of nonwords was used in Experiment 1A and 1B. Forty nonword targets consisting of two Kanji characters and having many neighbors ($M = 208.9$) were created for the lexical decision task. (The nonword stimuli are available from the authors upon request.) Nonwords were created by randomly combining two Kanji characters. 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, and 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.

Apparatus and procedure. Each participant was tested individually in a normally lit room. The experiment was programmed using the DMDX software package (Forster & Forster, 2003). Stimuli were presented on 21-inch video display driven by a desktop microcomputer. Primes were presented in a smaller font size (1.7 cm × 0.9 cm) than targets (2.5 cm × 1.3 cm) in order to minimize the physical overlap between primes and targets (in most other languages this is accomplished by using different letter cases for the primes and targets, e.g., a lowercase prime and an upper case target; however, a case manipulation is not possible with Kanji script). The sequence and timing of events during each trial were as follows. Each trial began with the presentation of a fixation marker ("+") in the center of the 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 then it 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 labeled buttons 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

Data from original participants with overall error rates greater than 20% were removed ($n = 4$ in Experiment 1A and $n = 1$ in Experiment 1B) and those individuals were replaced with 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 2–4). Response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and were excluded from all analyses (0.1% and 0.4% of word and nonword trials in Experiment 1A and 0.4% and 0.5% of word and nonword trials in 1B). In addition, data (related and unrelated trials)

[2] 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.

[3] 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 therefore the number of Kanji neighbors reported for stimuli in the present experiments is likely a significant overestimate of the actual number of neighbors existing in the mental lexicon of an average Japanese speaker. The number of neighbors for 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.

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

Stimulus characteristic	Target	Neighbor prime	Unrelated prime
High-frequency targets and low-frequency primes in Experiment 1A			
	選手 (/seNsju/, athlete)	助手 (/zjosju/, assistant)	反響 (/haNkjou/, echo)
Frequency	277.1	3.8	3.8
Neighbors	219.6	226.3	226.3
Low-frequency targets and high-frequency primes in Experiment 1A			
	助手 (/zjosju/, assistant)	選手 (/seNsju/, athlete)	影響 (/eikjou/, influence)
Frequency	3.8	277.1	277.1
Neighbors	224.0	219.6	219.6
High-frequency targets and low-frequency primes in Experiment 1B			
	選手 (/seNsju/, athlete)	右手 (/migite/, right hand)	検事 (/keNzi/, prosecutor)
Frequency	280.9	3.1	3.1
Neighbors	225.8	258.9	258.9
Low-frequency targets and high-frequency primes in Experiment 1B			
	右手 (/migite/, right hand)	選手 (/seNsju/, athlete)	仕事 (/sigoto/, job)
Frequency	3.1	280.9	280.9
Neighbors	258.9	225.8	225.8
Nonword targets and high-frequency primes in Experiment 1A and 1B			
	海泣	海外 (/kaigai/, overseas)	法案 (/houaN/, draft law)
Frequency	—	161.9	161.9
Neighbors	208.0	200.1	200.1
Nonword targets and low-frequency primes in Experiment 1A and 1B			
	手開	手首 (/tekubi/, wrist)	永遠 (/eieN/, eternity)
Frequency	—	2.7	2.7
Neighbors	209.9	202.4	202.4

from one low-frequency item presented in Experiment 1A (代休) and one low-frequency item presented in Experiment 1B (反物) were excluded from all analyses because the mean error rate for each item was greater than 50%.

For the word data, response latencies of correct responses and error rates were submitted to 2 (Prime Type: neighbor prime, unrelated prime) × 2 (Target Frequency: high, low) factorial analyses of variance (ANOVA). In the subject analyses, both factors were within-subject factors. In the item analyses, Prime Type was a within-item factor and Target Frequency was a between-item factor. For the nonword data, response latencies and error rates were analyzed with 2 (Prime Type: neighbor prime, unrelated prime) × 2 (Prime Frequency: low, high) factorial ANOVAs. In the subject analyses, both factors were within-subject factors; in the item analyses, Prime Type was a within-item factor and Prime Frequency was a between-item factor. The mean response latencies of correct responses and the mean error rates from the subject analyses are shown in Table 2.

Experiment 1A: Shared Constituent Character in Prime and Target has the Same Pronunciation

For word targets, the main effect of Target Frequency was significant in the analysis of response latencies, $F_s(1, 39) = 153.80$, $p < .001$, $MSE = 2112.47$, $\eta_p^2 = .80$; $F_i(1, 76) = 79.27$, $p < .001$, $MSE = 4894.50$, $\eta_p^2 = .51$, and in the analysis of errors, $F_s(1, 39) = 92.43$, $p < .001$, $MSE = 77.42$, $\eta_p^2 = .70$; $F_i(1, 76) = 31.47$, $p < .001$, $MSE = 233.23$, $\eta_p^2 = .29$. Lexical decisions to high-frequency targets (primed by low-frequency 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, $F_s(1, 39) = 5.28$, $p < .05$, $MSE = 73.96$, $\eta_p^2 = .12$; $F_i(1, 76) = 4.31$, $p < .05$, $MSE = 92.95$, $\eta_p^2 = .05$, 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 a Prime Type × Target Frequency 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.

Table 2
Experiment 1: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets

Prime type	RT	Errors	RT	Errors
Experiment 1A (shared constituent character with the same pronunciation)				
	Word targets			
	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			
	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
Experiment 1B (shared constituent character with different pronunciations)				
	Word targets			
	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			
	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

For the nonword targets, in both the analysis of response latencies and of errors, there was no effect of Prime Type, Prime Frequency, or their interaction (all *F*s < 1).

Experiment 1B: Shared Constituent Character in Prime and Target has Different Pronunciations

The pattern of results was very similar to that observed in Experiment 1A. For word targets, the main effect of Target Frequency was significant in both the analysis of response latencies, $F_s(1, 43) = 106.91$, $p < .001$, $MSE = 1790.60$, $\eta_p^2 = .71$; $F_i(1, 76) = 40.49$, $p < .001$, $MSE = 5250.49$, $\eta_p^2 = .35$, and of errors, $F_s(1, 39) = 139.83$, $p < .001$, $MSE = 53.74$, $\eta_p^2 = .77$; $F_i(1, 76) = 26.91$, $p < .001$, $MSE = 260.32$, $\eta_p^2 = .26$. Lexical decisions to high-frequency targets were faster and more accurate (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 1A, there was no main effect of Prime Type in the analysis of response latencies (both *Fs* < 1); response latencies to targets primed by orthographic neighbors (565 ms) were virtually identical to response latencies 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 1A, $F_s(1, 43) = 4.80$, $p < .05$, $MSE = 86.30$, $\eta_p^2 = .10$; $F_i(1, 76) = 5.51$, $p < .05$, $MSE = 70.07$, $\eta_p^2 = .07$. 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 in Experiment 1A, the interaction between Target Frequency and Prime Type was significant in the analyses of errors, $F_s(1, 43) = 4.58$, $p < .05$, $MSE = 65.68$, $\eta_p^2 = .10$; $F_i(1, 76) = 4.00$, $p < .05$, $MSE = 70.07$, $\eta_p^2 = .05$. Follow-up comparisons revealed that there was a significant 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 *t*s < 1).

For the nonword targets, in both the analyses of response latencies and of errors, there was no effect of Prime Type, Prime Frequency, or a Prime Type × Prime Frequency interaction (all *p*s $> .10$).

Combined Analyses With Experiment 1A and 1B

Although the results of Experiment 1A and 1B appear to be very similar, we carried out combined analyses of 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, $F_s(1, 82) = 6.99$, $p < .05$, $MSE = 67.30$, $\eta_p^2 = .08$; $F_i(1, 152) = 5.65$, $p < .05$, $MSE = 81.51$, $\eta_p^2 = .04$, and there was no three-way interaction of Experiment, Target Frequency, and Prime Type (both *F*s < 1), even though the Target Frequency × Prime Type interaction was significant only in Experiment 1B. Follow-up comparisons revealed a significant inhibitory priming effect for low-frequency targets primed by high-frequency neighbors, $F_s(1, 82) = 9.74$, $p < .01$, $MSE = 128.52$, $\eta_p^2 = .11$; $F_i(1, 76) = 8.88$, $p < .01$, $MSE = 137.99$, $\eta_p^2 = .11$, 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, $F_s(1, 82) = 6.30$, $p < .05$, $MSE = 1943.68$, $\eta^2 = .07$, which was not significant in the item analysis, $F_i(1, 152) = 2.58$, $p > .10$.

Discussion

In Experiment 1 we examined whether a neighbor priming effect would arise for two-character Kanji neighbor pairs. If lexical competition plays a role in the reading of Kanji words, one would expect some evidence of inhibition in either the latency or error data. In contrast, if lexical competition plays essentially no role in the reading of Kanji words, then a facilitory priming effect should have emerged for our Kanji neighbor pairs. Somewhat consistent with the former prediction, but inconsistent with the latter, we observed no effects on latencies and small inhibitory priming effects on error rates. 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 1A and 1B. This inhibitory priming effect could be interpreted as reflecting the operation of a lexical competition process during the reading of Kanji compound words. At the same time, the absence of such an effect on response latencies would suggest that the competition process is not as robust as it is for words in alphabetic scripts (e.g., Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990).

In Experiment 1A, the shared constituent character had the same pronunciation in the prime and target, whereas in Experiment 1B, the shared character had a different pronunciation in the prime and target. Regardless of this potentially important difference, the results of Experiment 1B were very similar to those of Experiment 1A—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. In Experiment 1B, unlike in Experiment 1A, the inhibitory priming effect was statistically significant only for low-frequency targets primed by high-frequency primes. Nonetheless, the data patterns were quite similar in the two experiments, which was confirmed by the lack of a significant interaction between Experiment and the pattern of priming effects. The similar results of the two experiments clearly indicate that, unlike the case with Chinese (i.e., Zhou et al., 1999), the shared phonology between neighbor pairs does not affect the priming effect from neighbor primes in Japanese Kanji. We will return to this point in the General Discussion.

The results of Experiment 1 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, morphological similarity should have led to a fairly large facilitation effect. Thus, our results could be accommodated by localist activation-based models by arguing that there were counteracting effects at different levels of processing: a facilitory effect due to morphological similarity and an inhibitory effect due to competition at the lexical level. That is, because the morphological overlap due to the common character in the neighbor pair would produce facilitory priming, any inhibitory priming effect due to lexical competition would be reduced or even eliminated.

If this argument is correct, then one prediction would be that there should be a significant facilitory priming effect from nonword Kanji neighbor primes (i.e., two-character Kanji nonword primes that share one constituent character with two-character Kanji compound word targets at the same character position;, e.g., 内火–内縁, "common-law"). That is, although nonword neighbor primes would not have a representation at the whole-word level, they would activate the lexical representations of their orthographic neighbors without producing strong competition for the target, as well as providing morphological priming due to the fact that they contain a morpheme also contained in the target. Therefore, facilitation processes should dominate. The purpose of Experiment 2 was to evaluate this prediction.

Experiment 2

Method

Participants. The participants were 40 undergraduate students from Waseda University (Tokyo, Japan). None of these students had participated in Experiment 1. All participants were native speakers of Japanese and reported having normal or corrected-to-normal vision.

Stimuli. Forty pairs of Kanji compound words were selected to serve as targets. These were the same neighbor pairs used in Experiment 1A, 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 1A, 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 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 any 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 2 are listed in Table 3. (The stimulus pairs used in Experiment 2 are listed in Appendix C.)

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 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 reassigning the prime-target pairs within the group. Unrelated primes did not share any characters with their targets. Thus, there were four prime-target conditions: (a) nonword neighbor prime–low-frequency target (e.g., 鉄手 – 助手, "assistant"); (b) unrelated nonword prime–low-frequency target (e.g., 犬響–助手, "assistant"); (c) nonword neighbor prime–high-frequency target (e.g., 鉄手–選手, "athlete"); and (d) unrelated nonword prime–high-frequency target (e.g., 犬響–選手, "athlete"). As before, these assignments were used to create four lists of stimuli which were presented to four different groups of participants. 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. A set of 40 nonwords, the same nonwords used in the previous experiments, were also presented as targets. In addition, 40 nonword neighbors were newly created to 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 targets were divided into two groups (of size 20). Unrelated nonword prime–nonword target

Table 3
Mean Normative Frequency (per Million Occurrences) and Number of Neighbors of Stimuli Used in Experiment 2

Stimulus characteristic	Target	Neighbor prime	Unrelated prime
	High-frequency targets and nonword primes		
	選手 (/seNsju/, athlete)	鉄手	犬響
Frequency	277.2	—	—
Neighbors	219.6	228.3	228.3
	Low-frequency targets and nonword primes		
	助手 (/zjosju/, assistant)	鉄手	犬響
Frequency	4.3	—	—
Neighbors	225.0	224.3	224.3
	Nonword targets and nonword primes		
	手開	手退	永低
Frequency	—	—	—
Neighbors	208.9	218.0	218.0

pairs were created by reassigning the original primes to other nonword targets. There were two counterbalancing lists for nonword target trials.

Apparatus and procedure. The apparatus and procedure were identical to those in Experiment 1.

Results

To be consistent with Experiment 1, original participants with overall error rates greater than 20% ($n = 4$) 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 (0.2% of word trials and 1.0% of nonword trials). For one low-frequency target (砂金), the mean error rate was greater than 50%; the prime-target pairs including this item were excluded from all analyses. For the word target data, response latencies of correct responses and error rates were submitted to 2 (Prime Type: neighbor prime, unrelated prime) × 2 (Target Frequency: low, high) factorial ANOVAs. In the subject analyses, both factors were within-subject factors. In the item analyses, 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 4.

For word targets, the main effect of Target Frequency was significant in the analysis of response latencies, $F_s(1, 39) = 174.51$, $p < .001$, $MSE = 1647.70$, $\eta_p^2 = .82$; $F_i(1, 77) = 63.32$, $p < .001$, $MSE = 5274.57$, $\eta_p^2 = .45$, and the analysis of errors, $F_s(1, 39) = 42.86$, $p < .001$, $MSE = 63.53$, $\eta_p^2 = .52$; $F_i(1, 77) = 26.66$, $p < .001$, $MSE = 107.61$, $\eta_p^2 = .26$. 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 Experiment 1, the main effect of Prime Type was significant in the analyses of response latencies, $F_s(1, 39) = 8.37$, $p < .01$, $MSE = 1054.11$, $\eta_p^2 = .18$; $F_i(1, 77) = 5.22$, $p < .05$, $MSE = 1568.61$, $\eta_p^2 = .06$. 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, $F_s(1, 39) = 6.20$, $p < .05$, $MSE = 1497.69$, $\eta_p^2 = .14$; $F_i(1, 77) = 5.48$, $p < .05$, $MSE = 1568.61$, $\eta_p^2 = .07$. 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 hand, there was no priming effect (both ts < 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 Fs < 1).

For nonword targets, the only significant effect was the main effect of Prime Type in the analysis of response latencies, $F_s(1, 39) = 5.00$, $p < .05$, $MSE = 819.65$, $\eta_p^2 = .11$; $F_i(1, 39) = 4.31$, $p < .05$, $MSE = 1011.22$, $\eta_p^2 = .10$. 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 Kanji nonword neighbor primes produce a different pattern of priming effects than the Kanji word neighbor primes used in Experiment 1. More specifically, when targets were primed by nonword neighbors there was a significant facilitory priming effect on response latencies that was restricted to the low-frequency targets. In contrast, when low-frequency targets were primed by word neighbors (Experiment 1) there was no facilitation effect on response latencies and an inhibitory priming effect on error rates.

According to localist activation-based models, a nonword does not have a representation at the whole-word level. A nonword prime could therefore create some lexical activation in the target's lexical representation, but no single lexical representation would be strongly activated. In addition, there would, of course, be

Table 4
Experiment 2: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets

	Word targets			
	Nonword prime–low-frequency target		Nonword prime–high-frequency target	
Prime type	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

activation of morphological representations based on the constituent characters. Thus, if the impact of word neighbor primes in Experiment 1 consisted of a facilitory component due to morphological (and orthographic) 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 2, along with the null effect on response latencies and the small inhibitory priming effect on error rates from word neighbor primes in Experiment 1, are consistent with the claim that lexical competition does play a role in the processing of Kanji compound words.

Experiment 3

The purpose of Experiment 3 was to assess the generality of the present data patterns. To do so, we selected a new set of stimuli and the effect of prime lexicality (word vs. nonword) was examined in a single experiment. We used only low-frequency targets 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 Experiment 1, we simply avoided using obviously semantically related word pairs, with the decisions about whether the prime-target pairs were semantically similar being based on one of the authors' judgment. Thus, it's not impossible that the semantic relatedness was not completely comparable for the word neighbor pairs and the unrelated word pairs. Because semantically related prime-target pairs are known to produce a significant semantic priming effect in the case of Chinese compound words in a masked priming situation (Zhou et al., 1999), or with a very short SOA (Chen et al., 2007), it is important to ensure that observed effects could not be contaminated by any semantic relatedness of neighbor prime-target pairs. In an effort to have even better control over this factor, in Experiment 3, we collected semantic relatedness ratings for our stimulus pairs, allowing us to equate our neighbor and unrelated pairs on this dimension.

In addition, unlike in the previous experiments, we selected a different set of unrelated primes rather than reassigning neighbor prime-target pairs in order to create the unrelated pairs, as was done in Experiments 1 and 2 (both of these procedures for creating unrelated pairs are standard procedures in the masked priming literature). When using Kanji compound stimuli, the reassigning 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 s, Ferrand, 1996; Forster & Davis, 1984; Versace & Nevers, 2003) and does not survive across intervening trials (Humphreys, Besner, & Quinlan, 1988), we wanted to completely rule out the possibility that the repetition of characters across trials could affect the pattern of the results observed in Experiment 3.

Lastly, we manipulated the lexical decision instructions provided to participants in order to assess whether this might be important for observing an inhibitory priming effect in the response latency data. Two groups of participants were provided with different lexical decision instructions. The participants in Experiment 3A, like the participants in Experiments 1 and 2, were instructed to respond as quickly and as accurately as possible, to encourage both rapid and accurate responding. The participants in Experiment 3B were instructed to give preference to accuracy over speed when responding. Both groups of participants responded to the identical word and nonword stimuli. De Moor, Verguts, and Brysbaert (2005) found that lexical decision instructions that stressed accuracy over speed led to a larger inhibitory neighbor priming effect in their masked neighbor priming experiments, presumably due to the fact that responding is more likely to be based on the activation level of the lexical unit for the presented target rather than contextual factors such as overall lexical activation (e.g., Grainger & Jacobs, 1996). We hypothesized that the same could be true for participants responding to our Kanji stimuli. Thus, by having participants give more emphasis to accuracy when responding, we hoped to increase the likelihood of observing an inhibitory neighbor priming effect in the response latency data.

Our expectation was that the data from Experiment 3A 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 on both latencies and error rates from nonword neighbors), which would provide additional confidence in the pattern of priming effects observed in Experiments 1 and 2 and the conclusions we derived from those effects. In Experiment 3B, we hoped to observe evidence of lexical competition in the response latency data.

Method

Participants. The participants were 96 undergraduate students from Waseda University (Tokyo, Japan). Forty-eight participated in Experiment 3A (with instructions emphasizing both speed and accuracy) and 48 participated in Experiment 3B (with instructions emphasizing accuracy). All were native speakers of Japanese and reported having normal or corrected-to-normal vision. None of these students participated in the previous experiments.

Stimuli. Sixty-four two-character Kanji compound words were selected to serve as targets. All the targets were of low-frequency, 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: (a) 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); (b) an unrelated higher frequency word (e.g., 責任, "responsibility"; these words had a mean normative frequency of 189.0); (c) a nonword that was an orthographic neighbor of the target (e.g., 支楽); and (d) 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). As noted, unlike the previous experiments, we used a different set of stimuli as unrelated primes (word and nonword) rather than reassigning neighbor prime-target pairs. The descriptive statistics for the stimuli are listed in Table 5 and the stimulus pairs are listed in Appendix D.

To collect semantic relatedness ratings for our word prime-word target pairs, we asked 44 undergraduate students from Waseda University (who did not participate in the lexical decision task) to rate the semantic relatedness of the prime-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: (a) a high-frequency word neighbor prime (e.g., 学生, "student"; these words had a mean normative frequency of 174.5); (b) a high-frequency unrelated word prime (e.g., 土地, "land"; these words had a mean normative frequency of 173.8); (c) a nonword neighbor prime (e.g., 師生); and (d) 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.

Apparatus and procedure. The apparatus was identical to that in the previous experiments. In Experiment 3A, like the previous experiments, participants were asked to respond as quickly and as accurately as possible, giving equal emphasis to accuracy and speed. In Experiment 3B participants were asked to emphasize accuracy when responding.

Results

Consistent with the previous experiments, original participants with overall error rates greater than 20% were replaced appropriately ($n = 9$ in Experiment 3A and $n = 1$ in Experiment 3B) and response latencies less than 300 ms or greater than 1,300 ms were treated as outliers and excluded from all analyses (0.9% of word trials and 0.8% of nonword trials in Experiment 3A; 1.4% of word trials and 2.4% of nonword trials in Experiment 3B). For one item (関脇) the mean error rate was greater than 50% in both experiments and the prime-target pairs including this item were excluded from all analyses. The mean response latencies of correct responses and the mean error rates for both word and nonword targets were analyzed with 2 (Prime Lexicality: word prime, nonword prime) × 2 (Prime Type: neighbor, unrelated) factorial ANOVAs. Prime Lexicality and Prime Type were within-subject factors in the subject analyses and within-item factors in the item analyses. The data for the word targets and the data for the nonword targets were analyzed separately. The mean response latencies and error rates from the subject analyses are listed in Table 6.

Experiment 3A: Lexical Decision Instructions Emphasizing Speed and Accuracy

For word targets, the main effect of Prime Lexicality was not significant in the analysis of response latencies or the analysis of errors (all Fs < 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, $F_s(1, 47) = 7.42$, $p < .01$, $MSE = 920.25$, $\eta_p^2 = .14$; $F_i(1, 62) = 5.45$, $p < .05$, $MSE = 2118.00$, $\eta_p^2 = .08$, and for errors, $F_s(1, 47) = 17.33$, $p < .001$, $MSE = 46.61$, $\eta_p^2 = .27$; $F_i(1, 62) = 19.73$, $p < .001$, $MSE = 55.45$, $\eta_p^2 = .24$. 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

Table 5
Mean Normative Frequency (per Million Occurrences) and Number of Neighbors of Stimuli Used in Experiment 3

Stimulus characteristic	Target	Word neighbor prime	Word unrelated prime	Nonword neighbor prime	Nonword unrelated prime
			Word targets		
	支障 (/sisjou/, trouble)	支持 (/sizi/, 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

Table 6
Experiment 3: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets

Experiment 3A (lexical decision instructions emphasizing both accuracy and speed)				
	Word Targets			
	Word prime		Nonword prime	
Prime type	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			
	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

Experiment 3B (lexical decision instructions emphasizing accuracy)				
	Word Targets			
	Word prime		Nonword prime	
	RT	Errors	RT	Errors
Neighbor	692	8.5	665	7.2
Unrelated	664	6.3	681	6.8
Difference	−28	−2.2	16	−0.4
	Nonword Targets			
	Word prime		Nonword prime	
	RT	Errors	RT	Errors
Neighbor	738	3.1	722	4.8
Unrelated	750	4.7	737	4.3
Difference	12	1.6	15	−0.5

they were primed by unrelated nonwords, $t_s(47) = 3.06$, $p < .01$, $SEM = 6.55$; $t_i(62) = 2.05$, $p < .05$, $SEM = 7.85$.

For the error analysis there was also an interaction between Prime Lexicality and Prime Type, $F_s(1, 47) = 17.33$, $p < .001$, $MSE = 46.61$, $\eta_p^2 = .27$; $F_i(1, 62) = 19.73$, $p < .001$, $MSE = 55.45$, $\eta_p^2 = .24$. This interaction was slightly different from, but consistent with, the corresponding interaction in the response latency analyses: When targets were primed by words the mean error rate was higher when they were primed by neighbors (a 5.4% inhibition effect), $t_s(47) = 3.62$, $p < .01$, $SEM = 1.48$; $t_i(62) = 3.05$, $p < .01$, $SEM = 1.78$, whereas when targets were primed by nonwords the mean error rate was somewhat lower when they were primed by neighbors (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 1 and 2.

For nonword targets, the only significant effect was the main effect of Prime Lexicality in the analyses of response latencies, $F_s(1, 47) = 7.03$, $p < .05$, $MSE = 1412.31$, $\eta_p^2 = .13$; $F_i(1, 63) = 3.47$, $p = .07$, $MSE = 2261.72$, $\eta_p^2 = .05$. Averaging over Prime Type (neighbor vs. unrelated), targets were responded to 15 ms faster when primed by nonwords than when primed by words.

Experiment 3B: Lexical Decision Instructions Emphasizing Accuracy

As can be seen in Table 6, changing the lexical decision instructions to emphasize accuracy resulted in much slower response latencies and smaller error rates both for word and nonword targets. The differences in overall response latencies and errors between Experiments 3A and 3B were all statistically significant (all $ps < .01$).

The change in the lexical decision instructions also produced a somewhat different pattern of priming effects. Like the situation in Experiment 3A, for the word targets neither the main effect of Prime Lexicality nor the main effect of Prime Type was significant (all $ps > .10$), and there was a significant interaction between Prime Lexicality and Prime Type, $F_s(1, 47) = 18.58$, $p < .001$, $MSE = 1205.05$, $\eta_p^2 = .28$; $F_i(1, 62) = 7.54$, $p < .01$, $MSE = 3195.32$, $\eta_p^2 = .11$. Unlike Experiment 3A, however, the interaction reflected the fact that word targets primed by word neighbors were responded to significantly slower than when they were primed by unrelated words. More specifically, follow-up comparisons revealed that word neighbor primes produced a 28 ms inhibitory priming effect, $t_s(47) = 4.07$, $p < .001$, $SEM = 6.8$; $t_i(62) = 2.34$, $p < .05$, $SEM = 11.8$, whereas nonword neighbor primes produced a 16 ms facilitory priming effect, $t_s(47) = 2.27$, $p < .05$, $SEM = 6.8$; $t_i(62) = 1.23$, $p > .10$. The 28 ms inhibitory priming effect contrasts with the 3 ms effect observed in Experiment 3A and demonstrates that, as we had speculated, changing the lexical decision instructions to emphasize accuracy over speed made it easier to produce an inhibition effect on response latencies. On the other hand, the inhibition effect observed in the error data of Experiment 3A was eliminated by the change in the lexical decision instructions, as there was no main effect of Prime Lexicality, Prime Type, nor an interaction (all $ps > .10$). As can been seen in Table 6, word neighbor primes produced a 2.2% inhibition effect versus the 5.4% inhibition effect in Experiment 3A.

For the nonword data, the main effect of Prime Lexicality was significant in the subject analysis of response latencies, $F_s(1, 47) = 5.55$, $p < .05$, $MSE = 1712.61$, $\eta_p^2 = .11$; $F_i(1, 63) = 3.11$, $p = .08$, $MSE = 3438.36$, $\eta_p^2 = .05$. As was the case in Experiment 3A, participants responded to targets faster when they were primed by nonwords than by words (a 15 ms difference). The main effect of Prime Type was significant in the subject analysis, $F_s(1, 47) = 5.14$, $p < .05$, $MSE = 1713.13$, $\eta_p^2 = .10$; $F_i(1, 63) = 1.19$, $p > .10$. For errors, there were no significant effects (all $ps > .10$).

Discussion

Although Experiment 3 involved a new set of stimuli, a different experimental design, and new groups of participants, the results were consistent with the results of the previous experiments—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. The inhibitory effect was again somewhat small and was observed only on error rates in Experiment 3A, whereas in Experiment 3B the effect was observed only on response latencies (although a small difference in the error rates was also present). These 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) and are most consistent with the conclusion that lexical competition plays a role in the processing of Kanji words. Our results also nicely converge with those of De Moor et al. (2005), who found that lexical decision instructions that stressed accuracy over speed produced a larger inhibitory neighbor priming effect.

As noted previously, part of the difficultly observing an inhibitory priming effect on response latencies in the word neighbor prime conditions in our experiments is likely due to the difference in morphological structure for English words versus Japanese Kanji compound words. The English words used by Davis and Lupker (2006) and Nakayama et al. (2008) were all monomorphemic words which were not at all morphologically similar, whereas the Kanji compound words used in the present experiments (and in Zhou et al.'s, 1999, experiments) were all polymorphemic words which shared a morpheme. As such, the masked word neighbor primes could produce two contrasting effects: facilitation at the morphological and, potentially, semantic levels, versus inhibition at the lexical level due to lexical competition. In contrast, neighbor primes and targets in English would not provide any morphological (or semantic) priming, and would therefore provide a better opportunity to observe the inhibition effects due to lexical competition. Note that because an attempt was made to not use semantically related prime-target pairs in our experiments, including collecting and equating the semantic relatedness ratings for the word neighbor pairs and the unrelated word pairs used in Experiment 3, any facilitation at the semantic level should have been minimal. Hence, the main facilitory priming component in any of the present experiments would have been due only to morphological similarity.

The results from our experiments can, therefore, be explained by assuming that inhibitory effects due to lexical competition can be counteracted by morphological facilitation. What should be noted, however, is that to our knowledge morphological priming effects have yet to be examined in the masked priming paradigm with Kanji compound words (in contrast to the extensive literature on morphological priming effects in alphabetic languages; e.g., Duñabeitia et al., 2009; Feldman et al., 2009; Fiorentino & Fund-Reznicek, 2009; Marslen-Wilson et al., 2008; Orfanidou et al., 2011; Rastle et al., 2004). Therefore, the purpose of our final experiment was to determine whether there are effects of morphological priming using Kanji compound words. We used the same word targets as used in Experiment 3, and each target (e.g., 支障, "trouble") was primed either by the same constituent character shared by the orthographic neighbors in Experiment 3 (e.g., 支), or by an unrelated single character (e.g., 引). We also collected semantic relatedness ratings for the single character prime-compound word target pairs (both for morphological and unrelated primes) to determine whether these primes and targets were semantically related. If our 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 identification relative to unrelated primes, a priming effect that should not be affected by the position of the constituent in the target (e.g., Shoolman & Andrews, 2003).

Experiment 4

Method

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

Stimuli. The same two-character Kanji compound words used in Experiment 3 served as targets, except for one item that was replaced due to a high-error rate (関脇 was replaced with 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 3. 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 3, we used a different set of stimuli as unrelated primes. The descriptive statistics for the stimuli are listed in Table 7 and the stimulus pairs are listed in Appendix E. The morphological primes and unrelated primes were matched in terms of mean character frequencies (M = 1,594.2 and 1,545.4 occurrences per million, respectively; Amano & Kondo, 2000) and mean number of strokes (M = 8.4 and 8.1). 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 3). 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 1,103.8 and 1,218.5 occurrences per million and the mean number of strokes were 8.7 and 8.8. Two counterbalancing lists were created for the nonword targets.

Apparatus and procedure. The apparatus was identical to that used in the previous experiments. For the lexical decision task,

Table 7
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 4

Stimulus characteristic	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

participants were instructed to respond as quickly and as accurately as possible.

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 (0.5% of word trials and 1.4% of nonword trials). One item (反吐) was excluded from all 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 a one-factor repeated measures ANOVA (Prime Type: morphological, unrelated). The mean response latencies and error rates from the subject analyses are listed in Table 8.

For word targets, there was a significant facilitation effect from morphological primes, both in the analyses of response latencies, $F_s(1, 35) = 29.63$, $p < .001$, $MSE = 572.06$, $\eta_p^2 = .46$; $F_i(1, 62) = 33.81$, $p < .001$, $MSE = 1220.63$, $\eta_p^2 = .35$, and in the analyses of errors, $F_s(1, 35) = 23.96$, $p < .001$, $MSE = 19.05$, $\eta_p^2 = .41$; $F_i(1, 62) = 13.54$, $p < .001$, $MSE = 60.88$, $\eta_p^2 = .18$. 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, $F_s(1, 35) = 4.47$, $p < .05$, $MSE = 43.80$, $\eta_p^2 = .11$; $F_i(1, 63) = 8.34$, $p < .01$, $MSE = 41.51$, $\eta_p^2 = .12$, but not on response latencies, $F_s(1, 35) = 2.49$, $p > .10$; $F_i(1, 63) = 3.97$, $p = .05$, $MSE = 1187.9$, $\eta_p^2 = .06$. 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%).

For word targets, to assess the effect of semantic transparency of the 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*).[4] As expected, morphologically related primes were rated as more semantically similar ($M = 4.4$, $SD = 1.1$) 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 transparency 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 transparency 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 transparency was not related to 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, we also looked at the effect of the position of the constituent primes 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 Prime Type 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%, whereas for targets primed by their second constituent the facilitory priming effects were 43 ms and 5.6%.[5]

Table 8
Experiment 4: Mean Lexical Decision Latencies (RT, in Milliseconds) and Percentage Errors for Word and Nonword Targets

Prime type	Word targets RT	Word targets Errors
Morphological	568	7.0
Unrelated	599	12.1
Difference	31	5.1
	Nonword targets RT	Nonword targets Errors
Morphological	645	10.9
Unrelated	637	7.6
Difference	−8	−3.3

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 transparency of the prime-target pairs or by the

[4] Determining the precise meaning of a single Kanji character can often be quite difficult because many single Kanji characters do not have an unambiguous meaning when they appear in isolation (see Tan & Perfetti, 1998; Weekes, Chen, & Lee, 1998, for a discussion of the analogous situation with single Chinese characters). However, the expectation was that to the extent that a pair received a high rating in this task, the relationship between the character prime and the word target was transparent to the participants. 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.

[5] In Experiments 1–3, approximately half of the neighbor prime-target pairs shared their first character and approximately half shared their second. To determine whether this factor mattered in those experiments, we examined the priming effects for low-frequency targets primed by high-frequency neighbors as a function of the position of the shared constituent character. For this analysis, the priming effects for items in Experiment 1A, 1B, and 3 were combined to increase the power of the analysis. The contrast involving prime-target pairs with the shared constituent character in the first ($n = 70$) versus the second position ($n = 71$) showed no interaction between positional overlap and priming, either in the analysis of response latencies, $F_i(1, 139) = 1.42$, $p > .10$, or in the analysis of errors, $F_i(1, 139) = 1.04$, $p > .10$. We also analyzed whether the priming effects were affected by the position of the shared constituent character for low-frequency targets primed by nonword neighbors. For this analysis, the items in Experiment 2 and 3 were combined. Here, again, priming effects were not significantly different for the neighbor pairs overlapping in the first ($n = 52$) versus the second character position ($n = 50$), as there was no interaction between positional overlap and priming, for both response latencies and errors (both Fs < 1). These results indicate that the position of the shared constituent character did not affect the pattern of priming effects to any noticeable degree in the present experiments.

position of the shared constituent, results consistent with the findings in other masked morphological priming studies (e.g., Fiorentino & Fund-Reznicek, 2009; Shoolman & Andrews, 2003). Together these results indicate that the morphological priming for compound Kanji words is similar to the morphological priming observed for words in alphabetic scripts.

Recall that in Experiments 1 and 3 an inhibitory priming effect from word neighbor primes was observed, although only on the errors rates unless participants were given lexical decision instructions that emphasized accuracy over speed (Experiment 3B). We hypothesized that this outcome was due to lexical competition being counteracted by morphological facilitation from shared constituent characters in neighbor pairs. In Experiment 4, we tested for this facilitory component directly by priming each target used in Experiment 3 with the same single Kanji character that was shared by the neighbors in Experiment 3. Considering that the same targets produced contrasting effects in Experiment 3 (where the primes were words that were orthographic neighbors of the targets) and Experiment 4 (where the primes were one of the constituent characters of the targets), the most reasonable conclusion seems to be that the lack of facilitation observed in response latencies from word neighbor primes (and the significant inhibition effect observed in error rates and, in Experiment 3B, in latencies) reflects inhibition effects that are, to some degree, counteracted by facilitory morphological priming effects.

General Discussion

The assumption of competition among the lexical units of orthographically similar words (i.e., orthographic neighbors) is one of the core assumptions of most 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 the target is primed by a high-frequency orthographic neighbor, due to the heightened competition between the lexical unit of the target and that of the neighbor. Previous masked priming studies using alphabetic languages (e.g., Davis & Lupker, 2006; Nakayama et al., 2008; Segui & Grainger, 1990) have reported results consistent with the predictions of localist activation-based models, namely, that lexical decision responses to a target would be slower when the target was primed by an orthographic neighbor than when it was primed by an unrelated word. Nakayama et al. (2011) have observed a similar inhibitory neighbor priming effect using Japanese Katakana words, suggesting that lexical competition process occurs in nonalphabetic languages as well. In contrast to the situation with alphabetic languages, far less is known about the impact of neighbor priming on the processing of words written in logographic scripts.

In the present research, we investigated the effect of masked priming using orthographic neighbors in Japanese Kanji. We reasoned that although Kanji neighbors differ in some ways from neighbors in alphabetic languages (e.g., the size of their neighborhoods), Kanji neighbors have the characteristics that are essential to the creation of lexical competition, namely, they share characters but they have distinct word-level representations. Therefore, if the lexical competition assumption is applicable to the processing of Kanji words then there should be an inhibitory component to masked neighbor priming effects in Kanji. An important consideration in this research, however, is the fact that Kanji neighbors are morphologically related (unlike orthographic neighbors in alphabetic scripts). Based on previous research examining masked morphological priming effects (e.g., Duñabeitia et al., 2009; Shoolman & Andrews, 2003; Zhou et al., 1999), the expectation was that there would be a facilitory component in the Kanji neighbor priming effect due to the shared constituent character of neighbor primes and targets.

In Experiments 1A, 1B, and 3A there was evidence of the presence of a lexical competition process, although the relevant effects were always confined to error rates, whereas in Experiment 3B an inhibitory neighbor priming effect was observed in the response latency data when participants were instructed to emphasize accuracy over speed when responding. These results do, of course, contrast to some degree with the previous masked priming studies using word neighbor primes in alphabetic languages (e.g., Andrews & Hersch, 2010; Davis & Lupker, 2006; De Moor & Brysbaert, 2000; Nakayama et al., 2008; Segui & Grainger, 1990) and with Katakana words (Nakayama et al., 2011), because in these previous studies the inhibition effects usually emerged in both response latencies and errors when participants were provided with standard lexical decision instructions (i.e., to respond as quickly and as accurately as possible). As we have argued, however, this difference between Kanji neighbor priming and priming in alphabetic languages is likely due to the fact that for Kanji script, inhibitory effects at the lexical level are counteracted by morphological facilitation.

Part of the basis for this conclusion is that the pattern of priming effects from word neighbor primes contrasts sharply with the clear facilitation effects from nonword neighbor primes (Experiment 2 and 3A) and from single constituent character primes (Experiment 4). That is, although target identification is significantly facilitated when a prime that is not a word contains a character also contained in the target, e.g., 支楽–支障, where the prime is a nonword neighbor of the target, or when the prime is the shared character itself (e.g., 支–支障), such facilitation turns negative when the character is presented as a constituent of a word prime (支持–支障). These contrasts provide good evidence that there is an inhibitory mechanism involved only in the word neighbor priming effect in Kanji and, therefore, the lexical competition assumption of the localist activation-based models is extendable to the word recognition processes involved in reading logographic scripts.

The Nature of Facilitory Priming in Kanji

As noted, a facilitory nonword neighbor priming effect has also been reported by most investigators working in alphabetic languages (e.g., Davis & Lupker, 2006; Forster et al., 1987; Forster & Veres, 1998; Perea & Rosa, 2000). These effects are typically explained in terms of the nonword neighbor prime activating the lexical representation of the target while not activating competitors sufficiently to produce any strong lexical competition. Although it is likely that similar processes were at work in the nonword prime conditions in the present experiments, it is also likely that the facilitory effects observed here are somewhat different than those in the previous literature in that they are mainly morphologically based. A consideration of the effects in this literature provides good support for this claim. In previous studies, the typical finding has been that nonword neighbor priming effects tend to be strong only 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 our experiments, we used two-character Kanji compound words as targets in both Experiments 2 and 3 and, hence, these targets were all high-neighborhood density words (M = 222.3 in Experiment 2 and M = 52.8 in Experiment 3). In addition, only one character was shared with the primes, and thus the degree of orthographic overlap (50%) was lower than is typically the case in experiments using English stimuli (at least 75%). As a consequence, it seems unlikely that any facilitation process at the lexical level in Kanji would have been particularly effective at producing priming (i.e., the activation created at the lexical level would have been quite diffuse). Therefore, it is probable that an additional facilitory factor must have been at work, most likely, morphology, based on the fact that there were clear morphological priming effects in Experiment 4.[6]

Note also that the facilitory priming effect from the nonword neighbor primes was limited to the low-frequency targets in Experiment 2. 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., lexical vs. morphological activation). At the same time, however, there could be an alternative explanation for this frequency difference. As can be seen in Table 4, 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 nothing more than 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 morphological facilitation. However, we should point out that with regard to the effect of relative prime-target frequency, our results are somewhat different from the inhibition effects reported in recent masked priming studies using English and Japanese Katakana words (Nakayama et al., 2008; Nakayama et al., 2011). In those studies, when target words had many neighbors, inhibition effects from neighbor primes were observed regardless of prime-target frequency. For instance, 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 localist 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 present experiments, the stimuli certainly had many neighbors (e.g., $M > 220$ in Experiment 1; also see Footnote 3). However, our data suggest that, even with all those neighbors, lexical competition plays very little role for low-frequency prime-high-frequency target pairs. The reasoning is that: (a) in Experiment 1A, 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 1B (0.5% vs. 5.4%); and (b) at the same time, in Experiment 2 there was no evidence of a facilitation effect for high-frequency targets primed by nonword primes (although the lack of a facilitation effect for high-frequency targets may have been due to a floor effect, as noted previously). That is, for high-frequency targets primed by low-frequency neighbors, the argument that the null priming effects reflect contrasting effects from facilitory morphological priming and inhibitory lexical level processing does not seem to follow, because, for these targets, there does not seem to have been any facilitation even when primed by nonwords. Therefore, these results seem to suggest that neither low-frequency word neighbors nor nonword neighbors have an ability to affect high-frequency targets, even if the primes have many neighbors.

One explanation for why high-frequency Kanji words were so impervious to priming, in contrast to what was observed by Nakayama et al. (2008), who used English targets, may be related to the proposal 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 words in alphabetic languages, the presentation of low-frequency primes may coactive their neighbors rapidly, producing at least a small degree of competition with high-frequency targets. For Kanji compound words, however, because the primes must be first analyzed morphemically, the coactivation of the prime's neighbors and, hence, their ability to compete, may grow somewhat more slowly. Indeed, it may be the case that this mandatory decomposition process, with the associated slowdown in the activation of neighbors, is another reason why the competition process appears to be weaker overall in Kanji than in alphabetic languages like English. This possibility should be an important consideration for future research examining neighbor priming in logographic languages.

[6] We cannot rule out the possibility that some of the facilitation observed in the present experiments may have arisen at the character level. Although there is very little evidence of priming at the letter level in alphabetic languages, previous masked priming studies suggest that facilitation due to mere form similarity is possible in Chinese character identification (Shen & Forster, 1991; Weekes, Chen, & Lee, 1998). That is, the prime "午", meaning "noon", facilitates responses to "牛", meaning "cow", relative to the prime "五", meaning "five". The effects of this factor in the present experiments, however, would likely have been quite minor.

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

The fact that word neighbor primes did produce a small inhibitory priming effect in our experiments means that our 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, we 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 (1999) experiments; as noted, the prime frequencies were somewhat lower than the target frequencies in their experiments. In our experiments, when we manipulated the relative frequencies of primes and targets, the inhibition patterns we observed only emerged when the prime frequencies were higher than the target frequencies, a condition Zhou et al. did not include in their experiments. More relevantly, there was little evidence of inhibition (or facilitation) for low-frequency prime–high-frequency target pairs like those used by Zhou et al. Therefore, the real question is not, why did we observe inhibition when Zhou et al. did not, but rather, why did we observe a null effect rather than the facilitation that Zhou et al. observed when using low-frequency primes and high-frequency targets?

A possible answer to that question is that the neighbor pairs used in the present experiments and those used in Zhou et al.'s (1999) experiments were different in terms of their semantic relatedness at the whole word level. That is, Zhou et al., for the purposes of their research, selected two types of neighbor pairs: the shared constituent character either denoted the same meaning in a prime and a target, or it did not. They did not equate the whole word semantic relatedness of the two types of neighbor prime-target pairs, nor did they equate the whole word semantic relatedness of neighbor prime-target pairs and unrelated prime-target pairs for each type of neighbor. However, they did report the whole word level semantic relatedness rating for one type of neighbor prime-target pairs. When the shared constituent denoted the same meaning, semantic relatedness ratings at the whole word level were very high, indicating that some of the facilitation effect may have been due to semantics. On the other hand, we selected our stimuli so that prime-target pairs (both neighbor pairs and unrelated pairs) were not semantically related at the whole word level, in order that our priming manipulation would not differ in this way from the manipulations used in studies involving alphabetic languages. It is therefore possible that the difference between the results of the present research and those of Zhou et al. may have been partially due to different degrees of semantic relatedness at the whole word level.

Another possibility is that the difference between our results and Zhou et al.'s (1999) is based on phonology. Recall that in Experiment 1, the pattern of the priming effects was essentially identical whether the shared character was pronounced the same way or not in a prime-target pair. In contrast, in Zhou et al., the phonology of the shared character significantly interacted with the priming effect pattern; specifically, the significant facilitation from orthographic neighbors diminished when the shared character was pronounced differently in a prime and a target. In fact, when the pronunciations differed, their results were comparable to our own—there was a null effect on response latencies and a (nonsignificant) inhibitory effect on error rates. These results may indicate that the nature of processing differs, at least to some degree, for Chinese versus Japanese compound words, with respect to the role of phonology, despite the apparent similarities of the two scripts.

One way in which Chinese and Japanese Kanji words do differ in terms of phonology is that most Chinese characters have a single pronunciation, and when a Chinese character is pronounced differently, it tends to have a different meaning (e.g., Verdonschot, Heij, Paolieri, Zhang, & Schiller, 2011; Verdonschot, Heij, & Schiller, 2010; Zhou & Marslen-Wilson, 1995), whereas most Kanji characters have multiple pronunciations, and even when a Japanese character is pronounced differently, it nevertheless tends to have the same meaning. For example, 親 is pronounced differently in the Kanji compound 両親 (/rjou*siN*/, "parents") than in the compound 母親 (/haha*oja*/, "mother"). Regardless of the pronunciation difference, this Kanji character denotes the same meaning ("parent"). Thus, it may be that when reading Chinese compound words, activation of higher level representations (e.g., morphological, semantic) is more likely to be affected by phonology. When reading Japanese Kanji words, on the other hand, the role of phonology in activating higher level representations may be less important. Therefore, it's possible that this difference in the visual recognition process of Chinese and Japanese Kanji words may also have played a role in producing the different results in Zhou et al. versus the present research. 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 between Chinese and Japanese Kanji words.

Implications for Connectionist Models

As noted above, the existence of lexical competition and intralexical inhibition is one of the key assumptions of localist models of lexical processing. The alternative to these types of models, connectionist models (e.g., Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989), make no such assumption. They are based on the principle that representations consistent with the input are activated while representations inconsistent with the input are either not activated or are inhibited. Therefore, the only impact a prime would have on an orthographically similar target would be facilitory. As such, these models could accommodate the finding of facilitory priming effects from nonword neighbors reported here, even though few of these models actually assume the existence of devoted morphological representations.

Connectionist models would, therefore, not only be consistent with our facilitation effects reported in Experiments 2, 3 and 4, but also with Zhou et al.'s (1999) results. In fact, as proposed by Zhou and Marslen-Wilson (2000), Zhou et al.'s 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" (p. 61). That is, this type of connectionist model would predict that the priming effect would be determined by the degree of featural overlap at the orthographic, phonological, and semantic (and potentially, morphological) levels, and thus a facilitory priming effect would be expected from Chinese neighbor primes, as they would share orthographic, phonological, morphological and, possibly, semantic features with their targets.

On the other hand, because connectionist models do not incorporate lexical representations at the whole word level, there would seem to be no obvious way for them to explain how a neighbor prime could produce an inhibition effect like that observed with alphabetic scripts and in our Experiments 1 and 3. Nor would these types of models be able to account for word and nonword neighbor primes affecting target identification differentially (e.g., Davis & Lupker, 2006; the present Experiments 1, 2 and 3), because the two prime types are equally similar to their targets on orthographic, phonological, semantic, and morphological dimensions. Clearly, the observation that inhibitory priming emerges at all, much less that it emerges most clearly in the situations where localist models would predict it to be most likely, poses a problem for connectionist models at their current state of development.

Conclusions

Localist activation-based models assume that lexical competition is a fundamental process in visual word identification. 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 compound words printed in Kanji, a logographic script. We conducted four lexical decision experiments with masked neighbor primes using Kanji compound words. We found that word neighbor primes had a significant inhibitory effect on error rates and, in certain circumstances, on response latencies. Nonword neighbor primes, in contrast, produced a significant facilitory priming effect on both response latencies and errors. In addition, the significant inhibition effects for 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 morphological prime). Taken together, these results support the conclusion that there is a lexical competition process involved in reading Kanji that is analogous to that observed in alphabetic languages. A key difference with Kanji neighbor priming, however, is that the inhibition due to lexical competition is counteracted by a facilitory priming effect at the morphological level. One goal for future research will be to more precisely delineate the interplay between inhibitory and facilitory processes in the reading of Kanji compound words.

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Appendix A

Stimuli for Experiment 1A

Words used in Experiment 1A					
High-frequency primes (Neighbor, Unrelated) and Low-frequency targets			Low-frequency primes (Neighbor Unrelated) and High-frequency targets		
選手 (sport player, athlete)	影響 (influence)	助手 (assistant)	助手 (assistant)	反響 (feedback)	選手 (sport player, athlete)
影響 (influence)	選手 (sport player, athlete)	反響 (feedback)	反響 (feedback)	助手 (assistant)	影響 (influence)
反対 (opposition)	以上 (more than)	反感 (aversion)	反感 (aversion)	机上 (on the desk)	反対 (opposition)
以上 (more than)	反対 (opposition)	机上 (on the desk)	机上 (on the desk)	反感 (aversion)	以上 (more than)
会談 (conference)	女性 (woman)	会報 (newsletter)	会報 (newsletter)	大意 (the general idea)	会談 (conference)
大会 (meeting, tournament)	会談 (conference)	大意 (the general idea)	大意 (the general idea)	酸性 (acidity)	大会 (meeting, tournament)
地域 (region)	首相 (prime minister)	地名 (geographic name)	地名 (geographic name)	時差 (time difference)	地域 (region)
時代 (era)	地域 (region)	時差 (time difference)	時差 (time difference)	宰相 (Chancellor)	時代 (era)
女性 (woman)	大会 (meeting, tournament)	酸性 (acidity)	酸性 (acidity)	会報 (newsletter)	女性 (woman)
首相 (prime minister)	時代 (era, time)	宰相 (chancellor)	宰相 (chancellor)	地名 (geographic name)	首相 (prime minister)
一部 (a part)	電話 (telephone)	一読 (read through)	一読 (read through)	神話 (mythology)	一部 (a part)
電話 (telephone)	一部 (a part)	神話 (mythology)	神話 (mythology)	一読 (read through)	電話 (telephone)

(*Appendices continue*)

Appendix A (*continued*)

Words used in Experiment 1A

High-frequency primes (Neighbor, Unrelated) and Low-frequency targets			Low-frequency primes (Neighbor Unrelated) and High-frequency targets		
指摘 (point out)	自宅 (home)	指数 (index numbers)	指数 (index numbers)	自供 (confession)	指摘 (point out)
自宅 (home)	指摘 (point out)	自供 (confession)	自供 (confession)	指数 (index numbers)	自宅 (home)
意見 (opinion)	生活 (life)	意地 (will power)	意地 (will power)	生還 (come back alive)	意見 (opinion)
生活 (life)	意見 (opinion)	生還 (come back alive)	生還 (come back alive)	意地 (will power)	生活 (life)
社長 (president)	計画 (a plan)	家長 (the head of a family)	家長 (the head of a family)	区画 (section)	社長 (president)
計画 (a plan)	社長 (president)	区画 (section)	区画 (section)	家長 (the head of a family)	計画 (a plan)
発表 (presentation)	企業 (enterprise)	発着 (departure and arrival)	発着 (departure and arrival)	学業 (school work)	発表 (presentation)
企業 (enterprise)	発表 (presentation)	学業 (schoolwork)	学業 (schoolwork)	発着 (departure and arrival)	企業 (enterprise)
言葉 (words)	資金 (funds)	言霊 (spirits of words)	言霊 (spirits of words)	砂金 (gold dust)	言葉 (words)
資金 (funds)	言葉 (words)	砂金 (gold dust)	砂金 (gold dust)	言霊 (spirits of words)	資金 (funds)
結果 (result)	内容 (content)	結社 (an association)	結社 (an association)	内縁 (common-law)	結果 (result)
内容 (content)	結果 (result)	内縁 (common-law)	内縁 (common-law)	結社 (an association)	内容 (content)
国際 (international)	制度 (system)	交際 (acquaintanceship)	交際 (acquaintanceship)	角度 (angle)	国際 (international)
制度 (system)	国際 (international)	角度 (angle)	角度 (angle)	交際 (acquaintanceship)	制度 (system)
協力 (cooperation)	全国 (nation-wide)	重力 (gravity)	重力 (gravity)	開国 (the opening of Japan)	協力 (cooperation)
全国 (nation-wide)	協力 (cooperation)	開国 (the opening of Japan)	開国 (the opening of Japan)	重力 (gravity)	全国 (nation-wide)
代表 (representative)	事件 (incident)	代休 (compensatory day-off)	代休 (compensatory day-off)	事典 (dictionary)	代表 (representative)
事件 (incident)	代表 (representative)	事典 (dictionary)	事典 (dictionary)	代休 (compensatory day-off)	事件 (incident)
組織 (organization)	銀行 (bank)	組成 (composition)	組成 (composition)	急行 (express)	組織 (organization)
銀行 (bank)	組織 (organization)	急行 (express)	急行 (express)	組成 (composition)	銀行 (bank)
国内 (domestic)	合意 (agreement)	家内 (wife)	家内 (wife)	合憲 (constitutional)	国内 (domestic)
合意 (agreement)	国内 (domestic)	合憲 (constitutional)	合憲 (constitutional)	家内 (wife)	合意 (agreement)

(*Appendices continue*)

Appendix A (*continued*)

Words used in Experiment 1A					
High-frequency primes (Neighbor, Unrelated) and Low-frequency targets			Low-frequency primes (Neighbor Unrelated) and High-frequency targets		
検討 (consideration)	中心 (center)	検問 (roadblock)	検問 (roadblock)	核心 (the core of an issue)	検討 (consideration)
中心 (center)	検討 (consideration)	核心 (the core of an issue)	核心 (the core of an issue)	検問 (roadblock)	中心 (center)
教授 (professor)	年度 (fiscal year)	教習 (training)	教習 (training)	年号 (name of an era)	教授 (professor)
年度 (fiscal year)	教授 (professor)	年号 (name of an era)	年号 (name of an era)	教習 (training)	年度 (fiscal year)
午前 (a.m.)	会社 (firm, company)	最前 (forefront)	最前 (forefront)	会費 (membership fee)	午前 (a.m.)
会社 (firm, company)	午前 (a.m.)	会費 (membership fee)	会費 (membership fee)	最前 (forefront)	会社 (firm, company)

Appendix B

Stimuli for Experiment 1B

Words used in Experiment 1B					
High-frequency Primes (Neighbor, Unrelated) and Low-frequency Targets			Low-frequency Primes (Neighbor, Unrelated) and High-frequency Targets		
選手 (sport player, athlete)	仕事 (job, work)	右手 (right hand)	右手 (right hand)	検事 (prosecutor)	選手 (sport player, athlete)
仕事 (job, work)	選手 (sport player, athlete)	検事 (prosecutor)	検事 (prosecutor)	右手 (right hand)	仕事 (job, work)
反対 (opposition)	以上 (more than)	反物 (roll of cloth)	反物 (roll of cloth)	年上 (a person older than oneself)	反対 (opposition)
以上 (more than)	反対 (opposition)	年上 (a person older than oneself)	年上 (a person older than oneself)	反物 (roll of cloth)	以上 (more than)
会談 (conference)	女性 (woman)	会得 (achieve, master)	会得 (achieve, master)	大雨 (heavy rainfall)	会談 (conference)
大会 (meeting, tournament)	会談 (conference)	大雨 (heavy rainfall)	大雨 (heavy rainfall)	相性 (compatibility)	大会 (meeting, tournament)
地域 (region)	首相 (prime minister)	地道 (low-profile)	地道 (low-profile)	時折 (occasionally)	地域 (region)
時代 (era)	地域 (region)	時折 (occasionally)	時折 (occasionally)	手相 (lines of the palm)	時代 (era)
女性 (woman)	大会 (meeting, tournament)	相性 (compatibility)	相性 (compatibility)	会得 (achieve, master)	女性 (woman)
首相 (prime minister)	時代 (era)	手相 (lines of the palm)	手相 (lines of the palm)	地道 (low-profile)	首相 (prime minister)
一部 (a part)	電話 (telephone)	一言 (a single word),	一言 (a single word)	小話 (short story)	一部 (a part)

(*Appendices continue*)

Appendix B (*continued*)

Words used in Experiment 1B

High-frequency Primes (Neighbor, Unrelated) and Low-frequency Targets			Low-frequency Primes (Neighbor, Unrelated) and High-frequency Targets		
電話 (telephone)	一部 (a part)	小話 (short story)	小話 (short story)	一言 (single word)	電話 (telephone)
指摘 (point out)	影響 (influence)	指先 (finger tip)	指先 (finger tip)	影絵 (shadow pictures)	指摘 (point out)
影響 (influence)	指摘 (point out)	影絵 (shadow pictures)	影絵 (shadow pictures)	指先 (finger tip)	影響 (influence)
意見 (opinion)	生活 (life)	下見 (preliminary inspection)	下見 (preliminary inspection)	生粋 (dyed in the wool, genuine)	意見 (opinion)
生活 (life)	意見 (opinion)	生粋 (dyed in the wool, genuine)	生粋 (dyed in the wool, genuine)	下見 (preliminary inspection)	生活 (life)
社長 (president)	計画 (plan)	気長 (patient, take one’s time)	気長 (patient, take one’s time)	図画 (arts and crafts)	社長 (president)
計画 (plan)	社長 (president)	図画 (arts and crafts)	図画 (arts and crafts)	気長 (patient, take one’s time)	計画 (plan)
発表 (presentation)	企業 (enterprise)	発作 (attack, seizure)	発作 (attack, seizure)	仕業 (an act, handiwork)	発表 (presentation)
企業 (enterprise)	発表 (presentation)	仕業 (an act, handiwork)	仕業 (an act, handiwork)	発作 (attack, seizure)	企業 (enterprise)
言葉 (a word)	資金 (funds)	言動 (speech and behavior)	言動 (speech and behavior)	針金 (a wire)	言葉 (a word)
資金 (funds)	言葉 (words)	針金 (a wire)	針金 (a wire)	言動 (speech and behavior)	資金 (funds)
結果 (results)	内容 (content)	結納 (engagement ceremony)	結納 (engagement ceremony)	内側 (inside)	結果 (results)
内容 (content)	結果 (result)	内側 (inside)	内側 (inside)	結納 (engagement ceremony)	内容 (content)
国際 (international)	制度 (system)	間際 (just before)	間際 (just before)	支度 (preparation)	国際 (international)
制度 (system)	国際 (international)	支度 (preparation)	支度 (preparation)	間際 (just before)	制度 (system)
協力 (cooperation)	全国 (nation-wide)	自力 (through one’s own effort)	自力 (through one’s own effort)	島国 (island country)	協力 (cooperation)
全国 (nation-wide)	協力 (cooperation)	島国 (island country)	島国 (an island country)	自力 (through one’s own effort)	全国 (nation-wide)
代表 (representative)	事件 (incident)	代物 (stuff, fellow)	代物 (stuff, fellow)	事柄 (affair, matter)	代表 (representative)
事件 (incident)	代表 (representative)	事柄 (affair, matter)	事柄 (affair, matter)	代物 (stuff, fellow)	事件 (incident)
組織 (organization)	銀行 (bank)	組曲 (suite)	組曲 (suite)	修行 (ascetic training)	組織 (organization)
銀行 (bank)	組織 (organization)	修行 (ascetic training)	修行 (ascetic training)	組曲 (suite)	銀行 (bank)

(*Appendices continue*)

Appendix B (*continued*)

Words used in Experiment 1B

High-frequency Primes (Neighbor, Unrelated) and Low-frequency Targets			Low-frequency Primes (Neighbor, Unrelated) and High-frequency Targets		
国内 (domestic)	合意 (agreement)	身内 (relatives)	身内 (relatives)	合間 (interim, interval)	国内 (domestic)
合意 (agreement)	国内 (domestic)	合間 (interim, interval)	合間 (interim, interval)	身内 (relatives)	合意 (agreement)
検討 (consideration)	中心 (center)	仇討 (revenge, vengeance)	仇討 (revenge, vengeance)	真心 (wholeheartedness)	検討 (consideration)
中心 (center)	検討 (consideration)	真心 (wholeheartedness)	真心 (wholeheartedness)	仇討 (revenge, vengeance)	中心 (center)
今年 (this year)	年度 (fiscal year)	今更 (it's too late to. . .)	今更 (it's too late to. . .)	年下 (a person younger than oneself)	今年 (this year)
年度 (fiscal year)	今年 (this year)	年下 (a person younger than oneself)	年下 (a person younger than oneself)	今更 (it's too late)	年度 (fiscal year)
午前 (a.m.)	会社 (firm, company)	気前 (generous-hearted)	気前 (generous-hearted)	会釈 (nodding, greeting)	午前 (a.m.)
会社 (company)	午前 (a.m.)	会釈 (nodding, greeting)	会釈 (nodding, greeting)	気前 (generous-hearted)	会社 (company)

Appendix C

Stimuli for Experiment 2

Words used in Experiment 2

Nonword primes (Neighbor, Unrelated) and Low-frequency targets			Nonword primes (Neighbor, Unrelated) and High-frequency targets		
鉄手	犬響	助手 (assistant)	鉄手	犬響	選手 (sport player, athlete)
犬響	鉄手	反響 (feedback)	犬響	鉄手	影響 (influence)
反蜜	泣上	反感 (aversion)	反蜜	泣上	反対 (opposition)
泣上	反蜜	机上 (on the desk)	泣上	反蜜	以上 (more than)
会犯	大姪	会報 (newsletter)	会犯	大姪	会談 (conference)
大姪	寅性	大意 (the general idea)	大姪	寅性	大会 (meeting, tournament)
地客	時橋	地名 (geographic name)	地客	時橋	地域 (region)
時橋	魅相	時差 (time difference)	時橋	魅相	時代 (era)
寅性	会犯	酸性 (acidity)	寅性	会犯	女性 (woman)
魅相	地客	宰相 (chancellor)	魅相	地客	首相 (prime minister)
一写	時話	一読 (read through)	一写	時話	一部 (a part)
時話	一写	神話 (mythology)	時話	一写	電話 (telephone)
指本	自誠	指数 (index numbers)	指本	自誠	指摘 (point out)
自誠	指本	自供 (confession)	自誠	指本	自宅 (home)
意策	生激	意地 (will power)	意策	生激	意見 (opinion)
生激	意策	生還 (come back alive)	生激	意策	生活 (life)

(*Appendices continue*)

Appendix C (*continued*)

Words used in Experiment 2					
Nonword primes (Neighbor, Unrelated) and Low-frequency targets			Nonword primes (Neighbor, Unrelated) and High-frequency targets		
鳥長	最画	家長 (the head of a family)	鳥長	最画	社長 (president)
最画	鳥長	区画 (section)	最画	鳥長	計画 (plan)
発変	熱業	発着 (departure and arrival)	発変	熱業	発表 (presentation)
熱業	発変	学業 (schoolwork)	熱業	発変	企業 (enterprise)
言子	召金	言霊 (spirits of words)	言子	召金	言葉 (words)
召金	言子	砂金 (gold dust)	召金	言子	資金 (funds)
結度	内火	結社 (association)	結度	内火	結果 (result)
内火	結度	内縁 (common-law)	内火	結度	内容 (content)
石際	菌度	交際 (acquaintanceship)	石際	菌度	国際 (international)
菌度	石際	角度 (angle)	菌度	石際	制度 (system)
犯力	線国	重力 (gravity)	犯力	線国	協力 (cooperation)
線国	犯力	開国 (the opening of Japan)	線国	犯力	全国 (nation-wide)
代聴	事日	代行 (replacement)	代聴	事日	代表 (representative)
事日	代聴	事典 (dictionary)	事日	代聴	事件 (incident)
組源	度行	組成 (composition)	組源	度行	組織 (organization)
度行	組源	急行 (express)	度行	組源	銀行 (bank)
描内	合回	家内 (wife)	描内	合回	国内 (domestic)
合回	描内	合憲 (constitutional)	合回	描内	合意 (agreement)
検紙	適心	検問 (roadblock)	検紙	適心	検討 (consideration)
適心	検紙	核心 (the center of an issue)	適心	検紙	中心 (center)
教卵	年算	教習 (training)	教卵	年算	教授 (professor)
年算	教卵	年号 (name of an era)	年算	教卵	年度 (fiscal year)
対前	会林	最前 (forefront)	対前	会林	午前 (a.m.)
会林	対前	会費 (membership fee)	会林	対前	会社 (firm, company)

Appendix D

Stimuli for Experiment 3

Words used in Experiment 3				
Word neighbor primes, word unrelated primes (English translation), nonword neighbor primes, nonword unrelated primes, and low-frequency targets (English translation).				
国家 (country, nation)	存在 (existence)	走家	走在	実家 (family home, parents' place)
開発 (development)	制度 (system)	開率	制率	開拓 (reclamation)
放送 (broadcast)	議論 (argument, discussion)	放本	議本	放火 (arson)
参加 (attendance)	国民 (the nation)	立加	立民	付加 (addition)
決定 (decision)	販売 (sales)	決人	販人	決闘 (battle, duel)
全国 (nation- wide)	予定 (engagement, plan)	全正	予正	全裸 (naked)
中心 (center)	市場 (market)	選心	選場	決心 (determination, decision)
保護 (protection)	維持 (maintenance)	決護	決持	養護 (care, nursing)
展開 (expansion)	投票 (vote)	芸開	芸票	満開 (in full blossom)
国連 (United Nations)	統一 (integration, coherence)	入連	入一	常連 (regular attendant)
期待 (expectation)	選手 (sport player, athlete)	号待	号手	接待 (business entertaining)
情報 (information)	幹部 (top official, executive)	情門	幹門	情緒 (affect)
価格 (price)	主張 (assertion, statement)	宮格	宮張	品格 (dignity, class)
平均 (average)	設置 (placement)	平隊	設隊	平年 (average year)
交渉 (negotiation)	利用 (use, take advantage of)	交倒	利倒	交番 (police box)
実施 (implementation)	国内 (domestic)	実来	国来	実権 (real power)
活動 (activities)	環境 (environment)	財動	財境	反動 (kick back)

(*Appendices continue*)

Appendix D (*continued*)

Words used in Experiment 3

Word neighbor primes, word unrelated primes (English translation), nonword neighbor primes, nonword unrelated primes, and low-frequency targets (English translation).

対象 (object, coverage)	結果 (results)	対情	結情	対岸 (opposite shore)
説明 (explanation)	電話 (telephone)	店明	店話	鮮明 (vivid, clearness)
議員 (assembly member)	会談 (conference)	脳員	脳談	店員 (shop clerk)
実現 (attainment, realization)	表明 (pronouncement)	実活	表活	実習 (apprenticeship)
新聞 (newspaper)	改正 (revision)	布聞	布正	見聞 (experience)
午後 (p.m.)	一部 (a part)	様後	様部	死後 (after death)
支持 (support)	責任 (responsibility)	支楽	責楽	支障 (interference, trouble)
改革 (revolution)	会議 (meeting, conference)	改年	会年	改札 (ticket gate)
団体 (association, entity)	法案 (bill, draft law)	凶体	凶案	液体 (liquid, fluid)
判断 (judgment)	監督 (boss, coach, director)	判標	監標	判読 (decipherment)
技術 (technology, skills)	導入 (implementation, adoption)	能術	能入	学術 (academic, scholarly)
報告 (report)	輸入 (import)	報有	輸有	報復 (retaliation, revenge)
現在 (present, now)	状況 (situation, status)	現死	状死	現物 (actual thing, spot commodity)
事実 (fact)	処理 (processing, disposal)	苦実	苦理	無実 (innocence)
市民 (citizen)	教育 (education)	青民	青育	漁民 (fisherman)
関連 (relevance, linkage)	組織 (organization)	関隙	組隙	関脇 (a rank in Sumo wrestling)
意見 (opinion)	社長 (president)	凍見	凍長	花見 (cherry-blossom appreciation party)
以上 (more than)	対応 (correspondence, handling)	滴上	滴応	真上 (directly overhead)
連合 (alliance, association)	政策 (policy, agenda)	愛合	愛策	歩合 (commission)
長官 (administrator, chief)	施設 (institution)	長母	施母	長靴 (boots)
安定 (stability, peace)	外交 (foreign diplomacy)	安減	外減	安物 (cheap stuff)
作品 (a piece of work)	人間 (human being)	作熱	人熱	作用 (action, function)
最高 (the best)	文化 (culture)	氏高	氏化	残高 (balance)
時間 (time)	外相 (foreign minister)	目間	目相	世間 (life, world, the public)
経営 (management)	自宅 (home)	経乾	自乾	経典 (religious scripture)
予定 (engagement, plan)	事業 (business pursuit, project)	獲定	獲業	勘定 (account, calculation)
野党 (opposition party)	今後 (from this time, future)	野段	今段	野原 (field)
政治 (politics)	今年 (this year)	麻治	麻年	全治 (full recovery)
生活 (life)	建設 (construction)	生料	建料	生首 (severed human head)
国際 (international)	姿勢 (posture, attitude)	家際	家勢	窓際 (beside the window)
内容 (content)	今回 (this time)	内質	今質	内訳 (breakdown)
合意 (agreement)	資金 (funds)	合黒	資黒	合宿 (camp)
強調 (emphasis)	拡大 (magnify, expand)	強里	拡里	強火 (high heat)
指摘 (point out)	支援 (support)	指約	支約	指図 (order, instruction)
銀行 (bank)	業界 (business field)	振行	振界	修行 (ascetic training)
貿易 (trading)	理由 (reason)	鳥易	鳥由	安易 (easy)
計画 (plan)	病院 (hospital)	左画	左院	版画 (print art)
平和 (peace)	言葉 (a word)	平源	言源	平手 (a flat hand)
子供 (child)	全体 (whole, entirety)	入供	入体	自供 (confession)
今年 (this year)	検討 (consideration)	壁年	壁討	享年 (age at death)
反対 (opposition)	仕事 (work, job)	反兵	仕兵	反吐 (vomit)
提案 (suggestion)	調査 (investigation, examination)	提神	調神	提灯 (Japanese paper lantern)
商品 (merchandise, goods)	行政 (public administration)	暑品	厚政	手品 (magic)
海外 (overseas)	写真 (picture)	海着	写着	海辺 (seashore)
立場 (position, standpoint)	事故 (accident)	区場	区故	劇場 (theater)
輸出 (export)	被告 (accused person)	位出	位告	家出 (running away from home)
背景 (background)	地方 (area, local region)	背養	地養	背骨 (backbone)

(*Appendices continue*)

Appendix E

Stimuli for Experiment 4

Words used in Experiment 4		
Morphological primes, unrelated primes, and low-frequency targets (English translation)		
家	取	実家 (family home, parents' place)
開	集	開拓 (reclamation)
放	革	放火 (arson)
加	区	付加 (addition)
決	五	決闘 (battle, duel)
全	氏	全裸 (naked)
心	午	決心 (determination, decision)
護	疑	養護 (care, nursing)
開	法	満開 (in full blossom)
連	調	常連 (regular attendant)
待	害	接待 (business entertaining)
情	利	情緒 (affect)
格	研	品格 (dignity, class)
平	言	平年 (average year)
交	先	交番 (police box)
実	最	実権 (real power)
動	理	反動 (kick back)
対	円	対岸 (opposite shore)
明	所	鮮明 (vivid, clearness)
員	前	店員 (shop clerk)
実	米	実習 (apprenticeship)
聞	演	見聞 (experience)
後	新	死後 (after death)
支	引	支障 (interference, trouble)
改	空	改札 (ticket gate)
体	運	液体 (liquid, fluid)
判	府	判読 (decipherment)
術	起	学術 (academic, scholarly)
報	局	報復 (retaliation, revenge)
現	要	現物 (actual thing, spot commodity)
実	表	無実 (innocence)
民	力	漁民 (fisherman)
芝	十	芝居 (a play)
見	京	花見 (cherry-blossom appreciation party)
上	入	真上 (directly overhead)
合	田	歩合 (commission)
長	政	長靴 (boots)
安	参	安物 (cheap stuff)
作	教	作用 (action, function)
高	通	残高 (balance)
間	東	世間 (life, world, the public)
経	資	経典 (religious scripture)
定	部	勘定 (account, calculation)
野	数	野原 (field)
治	共	全治 (full recovery)
生	代	生首 (severed human head)
際	使	窓際 (beside the window)
内	手	内訳 (breakdown)
合	市	合宿 (camp)
強	戦	強火 (high heat)
指	原	指図 (order, instruction)
行	金	修行 (ascetic training)
易	構	安易 (easy)
画	計	版画 (print art)
平	考	平手 (a flat hand)
供	英	自供 (confession)

(*Appendices continue*)

Appendix E (*continued*)

Words used in Experiment 4		
Morphological primes, unrelated primes, and low-frequency targets (English translation)		
年	日	享年 (age at death)
反	千	反吐 (vomit)
提	語	提灯 (Japanese paper lantern)
品	点	手品 (magic)
海	役	海辺 (seashore)
場	的	劇場 (theater)
出	事	家出 (running away from home)
背	因	背骨 (backbone)

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