ACADEMIC PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Journal of Memory and Language 48 (2003) 33–66

Journal of Memory and Language

www.elsevier.com/locate/jml

Masked repetition priming and word frequency effects across different types of Japanese scripts: An examination of the lexical activation account

Yasushi Hino,[a,*] Stephen J. Lupker,[b] Taeko Ogawa,[c] and Christopher R. Sears[d]

[a] *Institute for Advanced Studies in Artificial Intelligence, Chukyo University, 101 Tokodate, Kaizu-cho, Toyota, Aichi 470-0393, Japan*
[b] *Department of Psychology, The University of Western Ontario, Canada*
[c] *Graduate School of Human Informatics, Nagoya University, Japan*
[d] *Department of Psychology, University of Calgary, Canada*

Received 14 May 2001; revision received 5 September 2002

Abstract

In these experiments, cross-script masked repetition priming and word frequency effects were examined for Japanese words and nonwords as a function of script familiarity and the nature of the task (lexical decision or naming). In the lexical decision task, masked repetition priming effects were observed only for word targets and those effects were larger for targets presented in an orthographically unfamiliar script than for targets presented in an orthographically familiar script. In contrast, in the naming task, masked repetition priming effects were observed for both word and nonword targets and, for word targets, the repetition priming effects were similar regardless of the orthographic familiarity of the targets. In addition, large word frequency effects were observed when the targets were presented in a familiar script, but the effects were diminished or eliminated when the targets were presented in an unfamiliar script in both tasks. Implications of these results are discussed in terms of the possible loci of the priming effects in the two tasks.

Keywords: Cross-script masked repetition priming; Lexical activation; Abstract lexical units; Phonological activation; Script familiarity

The notions of a lexicon and a lexical-selection process have played central roles in many theoretical accounts of the word recognition process (e.g., Becker, 1976; Forster, 1976; McClelland & Rumelhart, 1981; Morton, 1969; Paap, McDonald, Schvaneveldt, & Noel, 1987; Paap, Newsome, McDonald, & Schvaneveldt, 1982; Rumelhart & McClelland, 1982). According to these types of accounts, each word in a reader's vocabulary is assumed to be represented as a lexical unit. Reading a word is assumed to involve a lexical-selection process in which the appropriate lexical unit is selected based on the visual input.

In recent years, however, the theoretical usefulness of this classical conceptualization of the lexicon has been challenged by a number of investigators. In fact, Seidenberg (1990) has argued that the concept of a lexicon itself has become essentially a "soupstone," that is, a concept that, although often included in models of word recognition, actually adds no explanatory power to those models. Similarly, the concept of a lexical-selection process has also been questioned by researchers. For example, classical lexical models have suggested that the lexical-selection process is the locus of word frequency effects, effects which are due to either frequency-sensitive lexical units (e.g., McClelland & Rumelhart, 1981; Morton, 1969; Rumelhart & McClelland, 1982) or a frequency-ordered serial search (e.g., Becker, 1976; Forster, 1976; Paap et al., 1987; Paap et al., 1982). Other

* Corresponding author.
E-mail address: hino@sccs.chukyo-u.ac.jp (Y. Hino).

0749-596X/02/$ - see front matter
PII: S0749-596X(02)00500-4

researchers, however, have suggested that word frequency effects are mainly due to task-specific processes and, thus, the lexical-selection process, if such a process indeed exists, plays only a minimal role in producing word frequency effects (e.g., Balota & Chumbley, 1984; Balota & Chumbley, 1985; Hino & Lupker, 1998, 2000; McCann & Besner, 1987; McCann, Besner, & Davelaar, 1988).

One result of the criticisms concerning the notions of the lexicon and lexical selection has been the emergence of word recognition models that postulate no lexicon nor lexical selection, models that are typically based on the parallel distributed processing (PDP) framework (e.g., Masson, 1999; Plaut, 1997; Plaut & McClelland, 1993; Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989; Van Orden, Pennington, & Stone, 1990). Contrary to classical lexical models, PDP models assume that words are represented as sets of subsymbols which themselves represent the orthographic, phonological, and semantic features of the words. That is, in PDP models, words are represented as patterns of activation among subsymbolic units and lexical knowledge is stored in the weights on connections among those units.

Given this theoretical challenge to classical lexical models, it is obviously rather important to reevaluate the empirical evidence supporting the notions of the lexicon and lexical selection. Although there are a number of lines of empirical evidence supporting these notions, in the present paper, we focus on only one of them: masked repetition priming effects.

According to the classical lexical models, it is generally assumed that the process of selecting an appropriate lexical unit is preceded by a preliminary abstract code generation process (e.g., Besner, 1983; Evett & Humphreys, 1981; Paap, Newsome, & Noel, 1984; Rayner, McConkie, & Zola, 1980). This process produces a set of orthographic codes which are independent of the nature of the visual characteristics of the word such as type font and letter case. Lexical units are then selected based on these abstract orthographic codes. Thus, the lexical units themselves are also assumed to be "abstract" in the sense that they are insensitive to the nature of visual forms of words.

A typical example of this type of model is Forster's (1976) lexical search model. According to this model, a stimulus description is first computed on the basis of the visual input and this stimulus description is compared with lexical entries in a serial manner. In particular, the entries for higher frequency words are examined before those for lower frequency words, which is what accounts for word frequency effects. When a correct match is found between the stimulus description and a lexical entry, that entry is selected.

The specific account of masked repetition priming effects within Forster's (1976) model is derived from Forster and Davis's (1984) results. Forster and Davis examined the effects of masked repetition priming as a function of word frequency in the lexical decision task. In their experiments, a briefly presented lowercase prime (60 ms duration) was preceded by an unrelated word (500 ms duration) and followed by an uppercase lexical decision target (500 ms duration). Forster and Davis observed that response latencies were faster when the uppercase targets were preceded by identical (but lowercase) primes than when the targets were preceded by different primes. The sizes of those effects were similar for high and low frequency targets. In addition, the masked repetition priming effect was limited to word stimuli and no masked priming effect was observed for orthographically similar pairs, pairs in which the prime and target differed only by one medial letter as in "lack—LOCK" (but see Forster, Davis, Schoknecht, & Carter, 1987).

Based on these results, Forster and Davis (1984) argued that, while lexical selection is mediated by orthographic representations, the masked repetition priming effect is due to lexical activation. Forster and Davis suggested that when a correct entry is located through the serial search process, a time-consuming access operation is executed to activate or "open" the entry. Once a lexical entry is opened, it remains "open" or activated for some period of time, so that subsequent access to the same entry would be facilitated independent of word frequency. This is the basis of the repetition priming effect. As such, according to Forster and Davis, masked repetition priming effects are presumed to be due to lexical activation, whereas word frequency effects are due to a frequency-ordered serial search process. (Hereafter this type of explanation of masked repetition priming effects will be referred to as the "lexical activation account.")

The observation of masked repetition priming effects across visually different stimuli (e.g., Evett & Humphreys, 1981; Forster & Davis, 1984) does provide nice evidence for the classical conceptualization of the lexicon and the lexical-selection process. That is, the fact that one can observe repetition priming when the prime and target share virtually no visual features is quite consistent with, and supportive of, the idea of automatic activation of a common, abstract lexical unit shared by the visually different prime and target. On the other hand, as Masson and colleagues (Bodner & Masson, 1997; Masson & Isaak, 1999) have pointed out, these effects may also have a nonlexical basis. That is, priming could also arise at either the orthographic level (where abstract orthographic codes are activated) or at the prelexical phonological level (where pre-lexical phonological codes are activated). (See Masson, 1999, for a simulation of masked repetition priming effects in a lexical decision task using his distributed memory model, a model that contains no lexical units.)

Masson and Isaak's (1999) results are particularly relevant here. Using a naming task, Masson and Isaak reported a masked repetition priming effect for nonwords that was similar in size to the masked repetition priming effect for words. Further, Masson and Isaak observed masked orthographic priming for nonwords that was also similar in size to that observed for words. Because nonwords do not, by definition, have lexical units, it is difficult for Forster and Davis's (1984) account (or any lexical activation account) to explain these results. More importantly, these results raise the question of whether masked repetition priming effects, in general, might be better explained in terms of orthographic, rather than lexical, structures. In the present research, we examined masked repetition priming effects for Japanese words across different types of scripts to further explore these issues.[1]

Japanese seems well-suited for this investigation because there is no relationship between the characters in the different scripts (in contrast, for example, to the relationship between upper and lower case Roman letters). Thus, although the same word written in different scripts should cause the same lexical unit to be selected, quite different orthographic units will be involved for the two scripts. Hence, any cross-script repetition priming that is observed could not be due to the prime and target activating identical orthographic units. (In "fully interactive" systems, it is possible that there could be a role for orthographic units in cross-script repetition priming effects, even in Japanese. We will return to this issue in the General discussion.)

Japanese scripts

There are three different types of scripts in the Japanese language. Japanese words can be written in either Kanji, Hiragana, or Katakana. These three script types can be divided into two classes in terms of their character-to-sound correspondences: syllabic Kana (Katakana and Hiragana) and logographic Kanji. Because each Kana character corresponds to a single mora (syllable), Kana is considered a shallow orthography, whereas Kanji is considered a deep orthography because each Kanji character generally corresponds to at least two pronunciations (On-reading and Kun-reading pronunciations).

In addition to the visual characteristics and the nature of character-to-sound correspondences, Japanese scripts also differ in their syntactic roles. That is, in normal sentences, Kanji characters are used for nouns as well as for verb and adjective stems. Katakana characters are used for foreign loan words, names of animals, flowers, vegetables, and some scientific terminology. Hiragana characters are mainly used for grammatical functions such as auxiliary verbs and inflections. As a result, a given word is usually written in one specific type of script. However, because both Katakana and Hiragana scripts are syllabic scripts, it is possible to transcribe any words into Hiragana or Katakana. On the other hand, because Kanji is not a syllabic script but a logographic script and, hence, its characters both carry meaning and typically have multiple pronunciations, it is rarely possible to transcribe Katakana-written or Hiragana-written words into Kanji.[2]

Due to these differences among scripts, it seems virtually impossible that they could share abstract orthographic units as are supposedly shared by upper and lower case Roman letters. Thus, when a word is transcribed into an unfamiliar script, lexical selection would have to be based on phonological codes. That is, through the use of phonological codes, lexical selection would be possible even for words written in unfamiliar scripts and, hence, our Japanese readers should be able to respond accurately in our lexical decision experiments regardless of the script type of the stimuli.

If cross-script masked repetition priming effects are observed in our experiments, therefore, an obvious implication would be that masked repetition priming effects are not due solely to pre-activation of orthographic units but rather are due to lexical activation, as suggested by Forster and Davis (1984). However, the lexical activation account would not be the only possible account of cross-script masked repetition priming effects. That is, as Masson and Isaak (1999) and Van Orden et al. (1990) have argued, masked repetition priming effects could be accounted for in terms of the activation of phonological units (see also Lukatela, Frost, & Turvey, 1998; Lukatela, Savic, Urosevic, & Turvey, 1997; Lukatela & Turvey, 1990; Lukatela & Turvey, 1994, for a phonologically based account of masked priming effects).

In fact, there now are a number of lines of evidence suggesting that automatic phonological activation oc-

[1] *Masked* repetition priming effects are typically assumed to be due to automatic activation of abstract lexical units shared by prime and target stimuli. In contrast, some researchers (e.g., Evett & Humphreys, 1981; Forster & Davis, 1984) argue that unmasked repetition priming effects are affected by strategic processes based on, for example, episodic memory traces. To examine the notion of abstract lexical units, therefore, we focused on masked repetition priming effects.

[2] Because Japanese scripts differ in their syntactic roles, presenting a word in an unfamiliar script could, in theory, cause somewhat different expectations in terms of the word's syntactic role. As our reason for presenting the same word in different scripts was simply to reduce the visual similarity and familiarity of stimuli and not to create any syntactic confusion, we attempted to minimize any potential problems by using only nouns that are normally written in either Kanji or Katakana.

curs early in the word recognition process not only in English (e.g., Lesch & Pollatsek, 1993; Lukatela & Turvey, 1990; Lukatela & Turvey, 1994; Lukatela et al., 1997; Lukatela et al., 1998; Perfetti, Bell, & Delaney, 1988; Van Orden, 1987; Van Orden, Johnston, & Hale, 1988) but also when reading Chinese characters and Japanese Kanji words (e.g., Perfetti & Zhang, 1991, 1995; Tan, Hoosain, & Peng, 1995; Wydell, Patterson, & Humphreys, 1993). In particular, Lukatela and Turvey (1994) reported significant phonological priming effects in naming tasks from masked homophone and masked pseudohomophone primes. Homophones are words sharing the same phonology (e.g., MADE—MAID) whereas pseudohomophones are nonwords with the same phonology as a real word (e.g., BRANE). Thus, although its phonology is the same as that of a real word, a pseudohomophone possesses a novel orthographic pattern. In this respect, pseudohomophones are similar to unfamiliar transcriptions of Japanese words (i.e., words written in an unfamiliar script). The idea would be that these masked primes (regardless of their orthographic familiarity) activate phonological units and these activated phonological units would be shared by a target with the same pronunciation (BRANE—BRAIN). If so, the possibility exists that masked repetition priming effects are a result of the prime pre-activating the target's phonological units and, hence, facilitating lexical selection via a phonological route. Hereafter this explanation of repetition priming will be referred to as the "phonological activation account."

The repetition by script familiarity interaction: Lexical decision

With respect to the present experiments, therefore, if masked repetition priming effects are observed for Japanese words across different script types, these effects could be explained by either the lexical activation account or the phonological activation account. Where the two accounts differ would be in the additional predictions they would make. For example, the two accounts make different predictions about the sizes of the cross-script masked repetition priming effects for word targets presented in familiar versus unfamiliar scripts in lexical decision tasks (see Table 1). First, consider the predictions of the phonological activation account. When word targets are presented in their familiar script, lexical selection for these words would be possible based directly on their familiar orthographic units. Thus, any phonological activation brought about by the masked prime would not play the major role in accomplishing lexical selection. On the other hand, when these words are transcribed into an unfamiliar script, lexical selection would have to be mediated by phonological units. If so, phonological activation due to the masked repetition prime would facilitate both phonological coding and, possibly, lexical selection for these words. Thus, assuming that lexical selection has to be accomplished to make a "word" decision in a lexical decision task, a larger masked repetition priming effect would be expected when word targets are presented in an unfamiliar script than when they are presented in their familiar script. (As noted, the phonological activation account offered here and, hence, these predictions, are based on the idea that classical lexical models are correct and that phonology's role is simply to provide one route to the lexicon. Both Masson & Isaak's (1999) and Van Orden et al.'s (1990) versions of the phonological activation account are based on models without lexical units (i.e., PDP-type models). We will consider these types of models in the General discussion.)

In contrast, the lexical activation account does not predict a repetition by script familiarity interaction. That is, repetition priming effects are due to the prime creating a heightened activation in the lexical unit of the

Table 1
Predictions from the lexical activation and the phonological activation accounts

Task	Account	
	Lexical activation account	Phonological activation account
Lexical decision	Repetition + Script Familiarity (No interaction)	Repetition × Script Familiarity (Larger repetition priming effect for unfamiliar script targets)
	Frequency + Script Familiarity (No interaction)	Frequency + Script Familiarity (No interaction)
Naming	Repetition × Script Familiarity (Larger repetition priming for familiar script targets)	Repetition + Script Familiarity (No interaction)
	Frequency × Script Familiarity (Larger frequency effect for familiar script targets)	Frequency × Script Familiarity (Larger frequency effect for familiar script targets)
	Repetition × Lexicality (No repetition priming effect for nonword targets)	Repetition + Lexicality (No interaction)

target. This heightened activation should facilitate selection of the target's lexical unit regardless of how lexical selection is accomplished (i.e., whether lexical selection is driven by orthographic units or phonological units). Thus, similar masked repetition priming effects are expected regardless of the script familiarity of the word targets.

The repetition by script familiarity interaction: Naming

The two accounts also differ in terms of their predictions in a naming task. Because naming tasks require pronunciation responses and, hence, phonological coding for all stimuli (e.g., Hino & Lupker, 1996; Seidenberg & McClelland, 1989; Waters & Seidenberg, 1985), phonological activation brought about by the masked repetition prime would facilitate phonological coding for all stimuli. Thus, according to the phonological activation account, masked repetition priming effects are expected for word targets regardless of script familiarity. In addition, this account also predicts a significant masked repetition priming effect for nonword targets (Masson & Isaak, 1999).

According to the lexical activation account, on the other hand, the masked repetition priming effect size in naming would depend on the degree to which phonological coding is mediated by lexical units. Nonwords, for example, which do not have lexical units, should show no masked priming. In addition, there are some word stimuli, in particular, words that are presented in a script that is both unfamiliar and shallow (i.e., Kanji words transcribed into Kana), that should also show very little masked repetition priming due to the fact that their phonological codes would typically be assembled without referring to lexical knowledge (e.g., Coltheart, 1978; Coltheart, Curtis, Atkins, & Haller, 1993). In contrast, as noted by Besner and Hildebrandt (1987), lexical phonological coding would be involved both for words written in a deep script like Kanji and for Kana-written words if they are typically seen in that script. Thus, these types of words should produce larger masked repetition priming effects than words presented in an unfamiliar shallow script. As such, the lexical activation account predicts a repetition by script familiarity interaction in the naming task.

Frequency effects

To evaluate these predictions, in the present experiments, cross-script masked repetition priming effects were examined as a function of the orthographic familiarity of the target stimuli in lexical decision and naming tasks. In addition, word frequency effects were also examined in these experiments in a further attempt to evaluate these two accounts. In all types of lexical models, the lexical-selection process is frequency dependent. For example, in Forster's (1976) model, the appropriate lexical unit is found after a frequency-ordered search in which the lexical units for high frequency words are checked first (see also Paap et al., 1982). Similarly, in Morton's (1969) logogen model, word frequency is encoded in the lexical units themselves and, hence, the process of selecting those units would be frequency sensitive regardless of what types of sublexical units were used in the selection process. Thus, although lexical selection would be driven by orthographic units when words are presented in their familiar script, and by phonological units when words are presented in an unfamiliar script, if lexical units are abstract and sensitive to word frequency, similar word frequency effects would be expected regardless of whether the script used was familiar or unfamiliar.

What the lexical activation account predicts, therefore, is that masked repetition priming effects and frequency effects should go together. Both masked repetition priming effects and frequency effects are expected in the lexical decision task for word targets regardless of whether they are presented in familiar or unfamiliar scripts. In the naming task, both of these effects are also expected when word targets are presented in their familiar scripts. When these words are presented in an unfamiliar shallow script, however, only very small effects are expected because lexical selection would be bypassed in the naming of these words.

A similar pattern of frequency effects is also predicted by the phonological activation account. Assuming that lexical selection has to be accomplished in making "word" decisions in the lexical decision task, frequency effects are expected for any type of word target. In the naming task, however, frequency effects are expected to be minimal for word targets that are presented in an unfamiliar shallow script.

To re-evaluate whether the notions of a lexicon and lexical selection are essential in explaining masked repetition priming effects, we examined cross-script masked repetition priming effects and word frequency effects as a function of the orthographic familiarity of the target stimuli in lexical decision (Experiments 1 and 2) and naming tasks (Experiment 3), by presenting primes and targets in different Japanese scripts. In Experiment 1, orthographically unfamiliar Katakana-transcription primes were followed by orthographically familiar Kanji-word targets for half of the participants, whereas orthographically familiar Kanji-word primes were followed by orthographically unfamiliar Katakana-transcription targets for the rest of the participants. In Experiments 2 and 3, unfamiliar Hiragana-transcription primes were followed by either familiar Katakana-word targets or unfamiliar Katakana-written targets which were transcribed from Kanji words.

Experiment 1

Method

Participants

A total of 48 undergraduate students from Chukyo University volunteered to participate in this experiment. All were native Japanese speakers and had normal or corrected-to-normal vision. Half of the participants received Kanji primes and Katakana targets whereas the other half received Katakana primes and Kanji targets.

Stimuli

Thirty-six Kanji words were collected from Japanese word frequency norms (National Language Research Institute, 1970). The Kanji words were all two-character nouns and were three or four syllables (moras) in length. Half of the Kanji words were high frequency words and half were low frequency words. The high frequency words each had a frequency count greater than 50 per 940,533. Each of the low frequency words had a frequency count of 5. The mean frequencies of the high and low frequency words were 105.4 and 5.0, respectively.

The high and low frequency Kanji words were matched on the number of syllables (moras), with a mean of 3.67 syllables for both groups of words. The summed Kanji character frequencies (National Language Research Institute, 1963) of the high and low frequency words were also equated as much as possible, with a mean summed character frequency of 758.44 for high frequency words and 752.06 for low frequency words, $t(34) = .04$. Orthographic neighborhood sizes were counted for these Kanji words. That is, the number of words created by replacing one character was counted for each word based on a computer-based dictionary with 36,780 word entries ("sakuin.dat" in National Language Research Institute, 1993). The mean orthographic neighborhood sizes were equated for the high and low frequency Kanji words as much as possible, with a mean neighborhood size of 44.44 for high frequency words and 41.83 for low frequency words, $t(34) = .31$. When these Kanji words were transcribed into Katakana, most of these transcriptions had no orthographic neighbors. In fact, there were only two low frequency transcriptions that had a single orthographic neighbor. As such, the means of orthographic neighborhood size were 0.00 and 0.11 for high and low frequency transcriptions, respectively.

This experiment consisted of two types of trials: Kanji–Katakana trials and Katakana–Kanji trials. In the Katakana–Kanji trials, these 36 Kanji words were used as targets and paired with Katakana-written primes. Two sets of Katakana prime–Kanji target pairs were created. Half of the high frequency and half of the low frequency Kanji targets were paired with their own Katakana transcriptions (repeated condition). The other halves of the words were each paired with a Katakana transcription of one of the other Kanji targets from the same frequency range (unrepeated condition). If a Kanji word was paired with its own Katakana transcription in the first set, it was paired with a Katakana transcription of a different Kanji word in the second set, and vice versa. Thus, the repeated and unrepeated conditions incorporated all 36 of the Kanji words as targets and all 36 Katakana transcriptions as primes.

For the purposes of the lexical decision task, 36 nonwords were created by randomly pairing two Kanji characters. These Kanji nonwords were used as targets and paired with Katakana primes. Two sets of Katakana prime–Kanji target nonword pairs were then created based on the 36 Kanji nonwords. In each set, half of the Kanji nonwords were paired with their own Katakana transcriptions (repeated condition), while the remainder were paired with Katakana transcriptions of other Kanji nonwords used in the experiment (unrepeated condition).[3] For these Kanji nonwords, the mean number of syllables was 3.67, with a range of 3–4. The words and nonwords used in the experiment were, therefore, matched on number of characters and number of syllables.

Given these word and nonword pairs, two stimulus sets were created by combining a set of word pairs with a set of nonword pairs. Thus, each stimulus set consisted of 72 pairs with 36 word pairs and 36 nonword pairs. Twelve participants were assigned to each stimulus set.

In the Kanji–Katakana trials, the 36 Kanji words were transcribed into Katakana and used as targets. These Katakana transcriptions were, then, paired with Kanji-word primes. In the same manner as in the Katakana–Kanji trials, two sets of Kanji word prime–Katakana transcription target pairs were created. In addition, two sets of nonword pairs were also created in the same manner as in the Katakana–Kanji trials, in which Katakana-transcription-nonword targets were paired with Kanji-nonword primes. The 36 Kanji nonwords used as targets in the Katakana–Kanji trials were used as Kanji-nonword primes. The Katakana transcriptions of these Kanji nonwords were used as targets.

[3] Because most Kanji characters have multiple pronunciations, only one of the possible pronunciations was arbitrarily chosen for each Kanji character for the purpose of transcribing the Kanji nonwords into Katakana. It is, of course, possible that, if asked to pronounce the Kanji nonwords, not all participants would have chosen to use that same pronunciation. Thus, "repeated" trials involving nonword primes and targets may not always have involved stimuli that would have been identically pronounced. Given that the focus of Experiment 1 was on the results from the word trials, this did not seem to be an important issue. In any case, the use of Hiragana in place of Kanji in Experiments 2 and 3 would completely eliminate any potential problems of this sort.

Again, two stimulus sets were created based on these word and nonword pairs. Each stimulus set consisted of 72 pairs. Twelve participants were assigned to each stimulus set. The 36 Kanji words and their Katakana transcriptions are listed in Appendix A.

Apparatus and procedure

Stimuli were presented on a video monitor (NEC, N5913) driven by an 8086-based computer (NEC, PC9801VM2). Participants indicated the lexicality of targets (word or nonword) by pressing one of two buttons on a response box interfaced to the computer. "Word" responses were made with the participants' dominant hand. The viewing distance was approximately 50 cm.

Participants were tested individually. Twenty-four participants were assigned to the Katakana–Kanji trials, whereas the rest of the participants were assigned to the Kanji–Katakana trials. Each trial began with a 50 ms 400 Hz warning tone, after which a fixation point appeared at the center of the video monitor. A trial sequence consisted of a forward mask, a prime, and a target presentation. Targets were all presented in the center of the screen just above the fixation point. The forward mask, consisting of six hash marks ("######"), was presented for 500 ms and was immediately replaced by the prime. The prime was presented for 32 ms and was immediately replaced by the target, which remained visible until the participant made a response. The onsets of the prime and target were synchronized with the vertical retrace signals of the video monitor. Participants receiving Katakana–Kanji trials were instructed to make a word-nonword discrimination to a Kanji string which appeared at the center of the video monitor as quickly and as accurately as possible by pressing either the "word" or "nonword" key on the response box. Participants receiving Kanji–Katakana trials were instructed to decide whether a presented Katakana string is a word transcribed into Katakana or a Katakana-written nonword. In both types of trials, the specific nature of a trial sequence was not mentioned. Lexical decision latency from the onset of the target to the participants' response and whether the response was correct were automatically recorded by the computer. Eighteen practice trials were given prior to the 72 experimental trials. During the practice trials, participants were provided with latency and accuracy feedback after each trial. No feedback was provided during the experimental trials. The order of the experimental trials was randomized separately for each participant. The intertrial interval was two seconds.

Results

Lexical decision latencies less than 250 ms or greater than 1600 ms were classified as errors and excluded from the latency analyses. A total of 48 data points (1.39%) were excluded in this fashion. Mean lexical decision latencies for correct responses and mean error rates were calculated across participants and items separately. The mean lexical decision latencies and error rates averaged over the participants are presented in Table 2.

Word trials

Subject and item means of lexical decision latencies and error rates for word trials were submitted to separate 2 (Frequency: high vs. low) × 2 (Repetition: repeated vs. unrepeated) × 2 (Trial Type: Katakana–Kanji trials vs. Kanji–Katakana trials) analyses of variance (ANOVAs). For the subjects' analyses, Frequency and Repetition were within-subject factors, whereas Trial Type was a between-subject factor. For the items' analyses, Repetition and Trial Type were within-item factors, whereas Frequency was a between-item factor.[4]

In the analyses of lexical decision latencies, the main effect of Trial Type, $F_s(1,46) = 65.39$, $MSe = 30939.74$, $p < .001$; $F_i(1,34) = 249.60$, $MSe = 6359.88$, $p < .001$, the main effect of Frequency, $F_s(1,46) = 64.63$, $MSe = 5094.02$, $p < .001$; $F_i(1,34) = 19.08$, $MSe = 15654.21$, $p < .001$, and the main effect of Repetition $F_s(1,46) = 81.85$, $MSe = 2941.59$, $p < .001$; $F_i(1,34) = 77.82$, $MSe = 2875.34$, $p < .001$, were all significant in both analyses.

The interaction between Frequency and Trial Type was significant in both analyses, $F_s(1,46) = 9.20$, $MSe = 5094.02, p < .01$; $F_i(1,34) = 6.02$, $MSe = 6359.88$, $p < .025$. The interaction between Repetition and Trial Type was also significant in both analyses, $F_s(1,46) = 47.12$, $MSe = 2941.59$, $p < .001$; $F_i(1,34) = 40.58$, $MSe = 2841.23, p < .001$. However, the interaction between Frequency and Repetition was not significant in either analysis, $F_s(1,46) = .85$, $MSe = 1738.90$; $F_i(1,34) = .76$, $MSe = 2875.34$, nor was the three-way interaction between Frequency, Repetition, and Trial Type, $F_s(1,46) = .53$, $MSe = 1738.90$; $F_i(1,34) = .12$, $MSe = 2841.23$.

[4] Although Clark (1973) has argued that items as well as subjects should be considered as a random factor in the analyses of variance when analyzing data from word recognition research, it is seldom the case that the selection of items ever is random in any sense of the term. That is, typically, the items used in these types of experiments have been selected because they satisfied an extensive set of criteria. Such is certainly the case here. As such, as a number of researchers (Cohen, 1976; Keppel, 1976; Raaijmakers, Schrijnemakers, & Gremmen, 1999; Smith, 1976; Wike & Church, 1976) have argued, items' analyses would clearly be inappropriate in the present situation for a number of reasons, not the least of which is their negative bias. Nonetheless, for the interested reader, the results of items' analyses will be reported. Our conclusions, however, will be based only on the results from the subjects' analyses.

Table 2
Mean lexical decision latencies in milliseconds and error rates in percent in Experiment 1

Condition		Repetition		RT difference
		Repeated	Unrepeated	
Unfamiliar Katakana transcription prime—familiar Kanji word target trials				
High frequency	RT	516 (51.18)	532 (36.99)	+16
	ER	1.39 (3.75)	2.31 (5.65)	
Low frequency	RT	629 (86.65)	647 (103.09)	+18
	ER	6.94 (9.16)	18.05 (15.65)	
Nonword	RT	688 (104.63)	685 (136.30)	−3
	ER	4.63 (5.35)	4.17 (7.73)	
Familiar Kanji word prime—unfamiliar Katakana transcription target trials				
High frequency	RT	703 (118.04)	818 (110.58)	+115
	ER	4.17 (8.55)	12.04 (11.77)	
Low frequency	RT	745 (133.06)	879 (124.24)	+134
	ER	6.94 (7.19)	19.91 (11.34)	
Nonword	RT	960 (173.16)	968 (184.61)	+8
	ER	9.72 (7.73)	7.87 (6.93)	

Note. RT and ER stand for mean reaction time and error rate, respectively. Standard deviation is in parenthesis.

To further investigate the significant interaction between Repetition and Trial Type, planned comparisons were conducted to examine the difference between the repeated and unrepeated conditions for each trial type by collapsing the Frequency factor. In the Kanji–Katakana trials, the 125 ms difference between the repeated and unrepeated conditions was significant in both analyses, $t_s(23) = 8.84$, $p < .001$ one-tailed; $t_i(35) = 10.11$, $p < .001$ one-tailed. In the Katakana–Kanji trials, the 17 ms repetition priming effect was also significant in both analyses, $t_s(23) = 2.00$, $p < .05$ one-tailed; $t_i(35) = 1.93$, $p < .05$ one-tailed. Thus, the Repetition by Trial Type interaction reflects the fact that the repetition priming effects were larger in the Kanji–Katakana trials than in the Katakana–Kanji trials.

Similarly, planned comparisons were also conducted to examine the differences between the high and low frequency conditions for each trial type by collapsing the Repetition factor. In the Katakana–Kanji trials, the 114 ms difference between the high and low frequency conditions was significant in both analyses, $t_s(23) = 8.11$, $p < .001$ one-tailed; $t_i(34) = 6.78$, $p < .001$ one-tailed. In the Kanji–Katakana trials, the 52 ms difference was also significant in both analyses, $t_s(23) = 3.37$, $p < .01$ one-tailed; $t_i(34) = 1.91$, $p < .05$ one-tailed. Thus, the significant Frequency by Trial Type interaction reflects the fact that frequency effects were larger for Kanji-word targets than for Katakana-transcription targets.

In the analyses of error rates, the main effect of Trial Type, $F_s(1,46) = 5.16$, $MSe = 119.72$, $p < .05$; $F_i(1,34) = 4.59$, $MSe = 100.90$, $p < .05$, the main effect of Frequency, $F_s(1,46) = 35.42$, $MSe = 86.40, p < .001$; $F_i(1,34) = 5.65$, $MSe = 406.13$, $p < .025$, and the main effect of Repetition, $F_s(1,46) = 32.99$, $MSe = 98.25$, $p < .001$; $Fi(1,34) = 26.35$, $MSe = 92.28$, $p < .001$, were all significant in both analyses.

The interaction between Frequency and Repetition was also significant in both analyses, $F_s(1,46) = 8.86$, $MSe = 79.02$, $p < .01$; $F_i(1,34) = 5.69$, $MSe = 92.28$, $p < .025$. The interaction between Frequency and Trial Type was marginally significant in the subjects' analysis, $F_s(1,46) = 3.94$, $MSe = 86.40$, $p < .06$, although not in the items' analysis, $F_i(1,34) = 2.53$, $MSe = 100.90$. The interaction between Repetition and Trial Type was not significant in either analysis, $F_s(1,46) = 2.36$, $MSe = 98.25$; $F_i(1,34) = 2.71$, $MSe = 64.14$, nor was the three-way interaction between Frequency, Repetition, and Trial Type, $F_s(1,46) = .98$, $MSe = 79.02$; $F_i(1,34) = .91$, $MSe = 64.14$.

Nonword trials

Subject and item means of lexical decision latencies and error rates for nonword trials were submitted to separate 2 (Repetition: repeated vs. unrepeated) × 2 (Trial Type: Katakana–Kanji trials vs. Kanji–Katakana trials) ANOVAs. For the subjects' analyses, Repetition was a within-subject factor, whereas Trial Type was a between-subject factor. For the items' analyses, both Repetition and Trial Type were within-item factors.

In the analyses of lexical decision latencies for nonword trials, the main effect of Trial Type was significant in both analyses, $F_s(1,46) = 41.20$, $MSe = 44967.60$, $p < .001$; $F_i(1,35) = 450.67$, $MSe = 6234.52, p < .001$. Participants responded faster to Kanji nonwords. Neither the main effect of Repetition nor the interaction between Repetition and Trial Type was significant in either analysis (all Fs $< .50$).

In the analyses of error rates, the main effect of Trial Type was significant in both analyses, $F_s(1, 46) = 6.37$, $MSe = 72.86$, $p < .025$; $F_i(1, 35) = 10.33$, $MSe = 67.40$, $p < .01$. Participants were more accurate with Kanji nonwords. Neither the main effect of Repetition nor the interaction between Repetition and Trial Type was significant in either analysis (all Fs < 1.3).

Discussion

Masked repetition priming effects were observed in lexical decision latencies and error rates for familiar Kanji-word targets and for unfamiliar Katakana-transcription targets even though, on both types of trials, the primes were presented in a different script than the targets. In addition, as was previously reported (e.g., Forster & Davis, 1984), masked repetition priming effects were not observed for nonword targets and, for word targets, the effect sizes were quite similar for high and low frequency words in the latency data, although the significant Frequency by Repetition interaction in the error data may indicate a tendency for the repetition priming effect to be a bit larger for low frequency words than for high frequency words.

The main aspects of these results were similar to those reported by Forster and Davis (1984). As previously noted, Forster and Davis suggested that masked repetition priming effects are due to lexical activation, whereas word frequency effects are due to a frequency-ordered serial search process leading to the selection of the appropriate lexical unit. Thus, the lack of an interaction between Frequency and Repetition observed in the latency data is consistent with their account. What needs to be addressed, however, is the fact that there was a significant interaction in the error data. In particular, the priming effect, in terms of error rates, for the high frequency words was substantially smaller than the priming effect for the low frequency words. At first glance, this result would appear to compromise the latency results. That is, one could argue that if, for example, the error rate in the low frequency, unrepeated condition had been lower, the latency in that condition and, hence, the size of the low frequency priming effect, would have been much larger. If so, the latency data would have shown a significant interaction.

Three points should be made here. First, as Forster and Davis (1984) noted, a Frequency by Repetition interaction is not inconsistent with all lexical models. In many of these models, Frequency and Repetition are both assumed to contribute to the process of lexical units being activated over their threshold (e.g., McClelland & Rumelhart, 1981; Morton, 1969). Whenever two factors affect the same process, it is not only possible but, in fact, likely that they would do so in an interactive fashion. Thus, a Frequency by Repetition interaction would certainly not be problematic for either lexical models or the lexical activation account, per se.

Second, because error rate is a different metric than latency, additive factors logic (Sternberg, 1969) actually does not apply. At a general level, the problem is simply that error rates are constrained to be between 0 and 100% whereas latency has no upper limit. For ease of discussion, consider what this means for the Kanji targets. In the unrepeated conditions, error rates were 2.3% for high frequency words and 18% for low frequency words. A repetition prime reduced the 18% error rate by over 11%. Such a reduction is simply not possible for the high frequency words. That fact would be true regardless of whether the priming manipulation affected the same process as frequency or not (i.e., whether additive factors' logic would say that the latency data would show an interaction or show additivity).

Finally, it may very well be true that if the participants had somehow been able to maintain the same error rate in the repeated and unrepeated conditions, an interaction would have emerged in the latency data. This point, however, turns out to have little relevance to Forster and Davis's (1984) model when one considers how errors emerge in the model. As in most processing models, errors reflect instances of inaccurate processing. In particular, in Forster and Davis's model, the 18% error rate for the low frequency Kanji words in the unrepeated condition would be due to the participants failing to recognize that they had found the correct lexical entry 18% of the time. The only way participants could have reduced that error rate would have been for them to go back and redo the lexical search. Although this would certainly have increased the latency in this condition, probably producing an interaction in the latency data, the latency in the low frequency, unrepeated condition would no longer be reflective of the time it takes to accomplish the processes described by the model. Thus, this artificially created interaction in the latency data would also not be reflective of the processes the model is trying to describe.

With respect to the main issue addressed in this experiment, it is clear that cross-script masked repetition priming effects do exist for Japanese words. It is also clear that these effects were limited to word stimuli. These results are consistent with the idea that abstract lexical units exist for Japanese words and that their activation is responsible for masked repetition priming effects. That is, these results support the claim that it is the activation of lexical units themselves that is producing the effects because Kanji words and their Katakana transcriptions do not share orthographic units. As noted previously, however, the existence of cross-script masked repetition priming in this experiment is also consistent with a phonological activation account. Let us turn then to the components of the data that may allow us distinguish between the two accounts, the Repetition by Trial Type (i.e., script familiarity) interaction and the Frequency effect.

The results indicate that there was a highly significant Repetition by Trial Type interaction (the cross-script masked repetition priming effects were larger for unfamiliar Katakana-transcription targets than for familiar Kanji-word targets). As noted in the Introduction, this result is more consistent with the phonological activation account than with the lexical activation account. What needs to be noted, however, is that the conditions in Experiment 1 may not have been the best conditions for examining this prediction. The reason is that the Trial Type manipulation involved not only different target types, but also different prime types (and different nonword types). That is, in this experiment, familiar Kanji-word targets were preceded by unfamiliar Katakana-transcription primes, whereas unfamiliar Katakana-transcription targets were preceded by familiar Kanji-word primes. It is certainly possible that the Kanji-word primes were processed more rapidly than the Katakana-transcription primes due to the fact that the Katakana-transcription primes are, in general, novel stimuli. If so, the lexical activation produced by the masked primes may have been weaker for the familiar Kanji-word targets than for the unfamiliar Katakana-transcription targets, resulting in the observed Repetition by Trial Type interaction. Thus, at this point, it is not entirely clear that this interaction was due to the familiarity difference between the Kanji and Katakana targets. This issue was re-examined in Experiment 2.

Consider next the word frequency effects for word targets presented in familiar and unfamiliar scripts. The Frequency by Trial Type (i.e., script familiarity) interaction was significant in the analyses of lexical decision latencies. Word frequency effects were significantly larger when targets were familiar Kanji words (114 ms effect) than when they were unfamiliar Katakana transcriptions (52 ms effect), although these frequency effects were significant for both types of stimuli. If one assumes that the lexical-selection process is frequency sensitive and that the same lexical unit is being selected for both target types, then this substantially smaller frequency effect for unfamiliar Katakana-transcription targets would appear to be problematic for any account based on classical lexical models, that is, it is problematic for both the lexical activation account and the phonological activation account.

According to the classical lexical models, the key process in lexical decision tasks is the lexical-selection process which, typically, is driven by the orthographic codes of the stimuli. Our purpose for using unfamiliar transcriptions as targets in the Kanji–Katakana trials was to make it necessary for participants to accomplish lexical selection based on phonological codes. If the same frequency-sensitive, abstract lexical units are selected by both Kanji words (via orthographic codes) and their Katakana transcriptions (via phonological codes), and if frequency effects are entirely due to the lexical-selection process, similar frequency effects should be observed for both target types.

More recently, however, some researchers have suggested that the classical lexical models need to add the assumption that, in a lexical decision task, a decision-making process is carried out based on stimulus familiarity either after lexical selection has been accomplished or concurrently with the lexical-selection process (e.g., Balota, 1990; Balota & Chumbley, 1984; Besner, 1983; Besner & McCann, 1987; Gernsbacher, 1984; McCann et al., 1988; Seidenberg, Waters, Barnes, & Tanenhaus, 1984). This process would, presumably, be frequency sensitive. Thus, observed word frequency effects would be due not only to the lexical-selection process but also to this decision-making process.

If such an assumption were added here, it would provide an explanation of why the frequency effects were different for the different scripts. For the Kanji words, the high frequency words would have benefited not only during lexical selection but also during this decision-making process. Thus, the size of the frequency effect observed for those stimuli would overestimate the impact of frequency on lexical selection (because part of the frequency effect would have arisen during the decision-making process). In contrast, when the words were transcribed into Katakana, even the high frequency words should have been novel orthographic patterns. Thus, the high frequency transcriptions may have benefited only during lexical selection. Therefore, the smaller frequency effect for the Katakana transcriptions would be perfectly consistent with this type of model.

Unfortunately, we did not attempt to measure and control the orthographic familiarity of our Katakana transcriptions beforehand, but rather simply assumed that they would all be unfamiliar to all our participants. Further, because these words are rarely written in Katakana, word frequency counts for the transcriptions, which would give us some idea of their orthographic familiarity, are not available. Thus, it is unclear whether there were differences in the orthographic familiarity of our high and low frequency transcriptions and, hence, whether the high frequency transcriptions did receive any extra benefit from the decision-making process or not.

To get some information on the question of orthographic familiarity in Experiment 1, therefore, we asked 72 participants to rate the orthographic familiarity of the 36 Kanji words used in the experiment, as well as their Katakana transcriptions. None of these participants had participated in Experiment 1.

Orthographic familiarity ratings were collected for the 36 Kanji words as well as for their Katakana and Hiragana transcriptions. Three stimulus lists were created, each of which consisted of 12 Katakana transcriptions, 12 Hiragana transcriptions, and 12 Kanji-written Kanji words. Each Kanji word was presented in Kanji in one list, in Hiragana in a second list, and in Katakana in a third list. Thus, each word appeared only once in a list. Each list was presented to one-third of the 72 participants. Each stimulus list was randomly ordered and listed in a questionnaire. Each item was accompanied by a seven-point scale ranging from "Very Unfamiliar" (1) to "Very Familiar" (7) on the questionnaire. The participants were asked to rate the orthographic familiarity of each item by circling the appropriate number on the scale. Participants were also instructed that the printed form of each item should be taken into consideration when rating familiarity.

For the high and low frequency Kanji words written in Kanji, the mean orthographic familiarity ratings were 5.87 and 4.80, respectively. The mean orthographic familiarity ratings for the Katakana transcriptions of these high and low frequency Kanji words were 2.91 and 2.32, respectively. These rating data were submitted to a 2 (Frequency: high vs. low) $\times$ 2 (Script Type: Kanji vs. Katakana) ANOVA. Because the same words were presented in Kanji and Katakana scripts, Script Type was treated as a within-item factor, whereas Frequency was treated as a between-item factor. The main effect of Frequency was significant, $F(1, 34) = 30.88$, $MSe = .40$, $p < .001$. As expected, high frequency words were given higher ratings than low frequency words. The main effect of Script Type was also significant, $F(1, 34) = 774.87$, $MSe = .17$, $p < .001$, as the words written in Kanji were given higher ratings overall than their Katakana transcriptions. Further, there was a significant interaction between Frequency and Script Type, $F(1, 34) = 6.09$, $MSe = .17$, $p < .025$, indicating that the frequency effect was larger for Kanji words than for their Katakana transcriptions. Simple main effects tests, however, showed that not only were the orthographic familiarity ratings significantly higher for high frequency words than for low frequency words when those words were written in Kanji, $t(34) = 5.03$, $p < .001$, they were also significantly higher when those words were written in Katakana, $t(34) = 4.31$, $p < .001$.

The rating data, therefore, indicate that our participant population actually did find our high frequency transcriptions more orthographically familiar than our low frequency transcriptions in spite of the fact that we had assumed that both would be novel visual forms. Thus, the possibility certainly exists that our high frequency transcriptions benefited during the decision-making process as well as during the lexical selection process. However, as the interaction indicates, it is unlikely that they benefited during the decision-making process to the same degree as the high frequency Kanji words did. Thus, these ratings results would readily explain the finding of a smaller frequency effect for the transcriptions without causing any difficulties for either of the two accounts.

This result, however, does raise a further issue. Given that the interaction observed in the rating data nicely parallels the interaction observed in the latency data, one could argue that the entire frequency effect was caused by the decision-making process. Such a perspective would severely diminish the role of the lexical units in explaining word frequency effects. This issue was also addressed in Experiment 2.

Experiment 2

The results of Experiment 1 demonstrated very clear masked repetition priming effects in Japanese, effects that are predicted by both accounts being considered. Word frequency effects were, however, smaller for the unfamiliar transcriptions than for the familiar Kanji words, an effect which is not consistent with classical lexical models in general. To account for this result in terms of the classical lexical models we must assume that lexical decision tasks also involve a frequency-sensitive decision-making process, a process that is based on orthographic familiarity. Once one makes this assumption, the question arises as to whether the frequency effects in Experiment 1 might have been entirely due to this process rather than to the lexical-selection process. Such a conclusion would clearly be inconsistent with classical lexical models.

In Experiment 2 we attempted to address this issue by making certain that the high and low frequency transcription targets were equated on orthographic familiarity. Thus, any frequency effect we obtain for those targets can really be attributed to the lexical-selection process.

Another issue that we addressed in Experiment 2 was the larger cross-script masked repetition priming effect for the unfamiliar Katakana-transcription targets than for the familiar Kanji-word targets. Although the repetition by script familiarity interaction is problematic for the lexical activation account, because the orthographic familiarity of the primes was not identical and because different types of nonwords were used in the two types of trials, it was unclear whether this interaction in Experiment 1 was really due to the script familiarity of the targets.

To address this issue, in Experiment 2 we examined the same questions with a better control on the orthographic familiarity of primes and targets. That is, we once again examined the main issue of this research, the question of whether there are cross-script masked repetition priming effects in Japanese. In this experiment, however, all the primes were written in the same script (Hiragana) and all the targets (both words and nonwords) were written in the same script (Katakana). One set of targets involved Japanese words that are usually written in Katakana (e.g., foreign loan words). These words are like the Kanji-word targets in Experiment 1 in that they are words which should be orthographically familiar to the participants. The second set of targets involved Kanji words that were transcribed into Katakana as was also done in Experiment 1. These targets should be orthographically unfamiliar to our participants. Most importantly, orthographic familiarity was controlled in Experiment 2 by collecting orthographic familiarity ratings for all targets and primes prior to the experiment. For the Katakana-word targets, the high frequency words will, of course, be rated higher in familiarity than the low frequency words. For the Katakana-transcription targets, however, it was possible to select high and low frequency transcriptions that were matched on orthographic familiarity. Thus, any frequency effects for the Katakana-transcription targets in Experiment 2 can be attributed to the lexical-selection process.

In addition, to make the parallel to Experiment 1 complete, the familiar Katakana-word targets and the unfamiliar Katakana-transcription targets were presented in different blocks in Experiment 2. However, because word targets were written only in Katakana in both blocks, the nonwords were also written in Katakana and the same nonwords were used (in a counterbalanced fashion) in the two blocks. Further, the orthographic familiarity of the Hiragana primes was matched across conditions. As such, different results between the two blocks, if any, cannot be attributed to either a prime type difference or a nonword type difference in this experiment.

Method

Participants

Twenty-four undergraduate students from Chukyo University participated in this experiment for course credit. All were native Japanese speakers who had normal or corrected-to-normal vision. None had participated in Experiment 1.

Stimuli

A sample of 120 Kanji words and 120 Katakana words were selected from the Japanese word frequency norms (National Language Research Institute, 1970). The Kanji words were words that were listed in Kanji in the frequency norms. Similarly, the Katakana words were words that were listed in Katakana in the frequency norms. All the words were nouns. The Kanji words were all two characters in length and consisted of three or four syllables (moras). The Katakana words were three or four characters in length and consisted of three or four syllables. Half of the Kanji and Katakana words were high frequency words, with frequency counts of greater than 20 per 940,533. The remaining words were low frequency, with frequency counts less than or equal to 10.

As in Experiment 1, most of these Kanji words are normally written only in Kanji. Similarly, most of these Katakana words are normally written only in Katakana. Thus, for the Katakana and Hiragana transcriptions of the Kanji words and for the Hiragana transcriptions of the Katakana words, it was not possible to estimate their orthographic familiarity based on word frequency counts because publications of such frequency counts do not exist. As such, orthographic familiarity ratings were collected for this sample of 240 Kanji and Katakana words. Ninety participants were asked to rate the orthographic familiarity for the Kanji, Katakana, and Hiragana forms of the Kanji words, and the Katakana and Hiragana forms of the Katakana words using the same rating procedure as used when rating the orthographic familiarity of the words used in Experiment 1. That is, three different questionnaires were created. Each Kanji word appeared in all versions of the questionnaires but in a different type of script. For example, a Kanji word which was listed in its Kanji form in one version appeared in a second version in its Hiragana transcription, and in a third version in its Katakana transcription. For the Katakana words, the Katakana forms and their Hiragana transcriptions also appeared in two of the three versions of the questionnaires. Thus, each version of the questionnaire consisted of 200 items, in which 40 Kanji forms of Kanji words, 40 Hiragana transcriptions of Kanji words, 40 Katakana transcriptions of Kanji words, 40 Katakana forms of Katakana words, and 40 Hiragana transcriptions of Katakana words were contained. The 200 items were randomly ordered in each version of the questionnaires. Each item was accompanied by a seven-point scale ranging from "Very Unfamiliar" (1) to "Very Familiar" (7). The 90 participants were asked to rate the orthographic familiarity of each of these items by circling the appropriate number on the scale. Thirty participants were assigned to each of the three versions of the questionnaire.

Based on the orthographic familiarity ratings, 60 Kanji words and 60 Katakana words was selected for use in this study. Four word groups, each containing 30 words, were created: (1) high frequency Kanji words, (2) low frequency Kanji words, (3) high frequency Katakana words, and (4) low frequency Katakana words. The mean syllabic length was 3.40 in all four groups, with a range of 3–4. Because each Kana character (Hiragana and Katakana) generally corresponds to a syllable (mora), when Kanji words are transcribed into Hiragana or Katakana, the word length of those Kana transcriptions would be identical to the syllabic length of the original Kanji words. In fact, when these words were written in Katakana or Hiragana, word length was matched across the four groups.

The orthographic familiarity ratings for the Katakana forms were submitted to a 2 (Word Type) × 2 (Frequency) ANOVA. The main effect of Word Type was significant, $F(1, 116) = 993.98$, $MSe = .31$, $p < .001$, as orthographic familiarity ratings were greater for the Katakana words than for the Katakana transcriptions of Kanji words. The main effect of Frequency was significant, $F(1, 116) = 13.90$, $MSe = .31, < .001$, as was the interaction between Word Type and Frequency, $F(1, 116) = 10.65$, $MSe = .31$, $p < .01$. For the Katakana words, the high frequency words had significantly higher orthographic familiarity ratings than the low frequency words (5.81 vs. 5.11: $t(58) = 4.07$, $p < .001$), whereas the orthographic familiarity ratings for the high and low frequency Katakana transcriptions of Kanji words were quite comparable (2.30 vs. 2.25: $t(58) = .45$).

In addition, orthographic neighborhood size was determined for each Katakana form used in this experiment based on National Language Research Institute (1993). Although the orthographic neighborhood sizes were somewhat larger for the Katakana words than for the Katakana transcriptions of Kanji words, they were quite comparable between high and low frequency Katakana words (2.30 vs. 2.20: $t(58) = .12$) and between high and low frequency Katakana transcriptions (.73 vs. .63: $t(58) = .19$).

Orthographic familiarity ratings for Hiragana transcriptions of these stimuli were also matched across the four groups. A 2 (Word Type: Katakana word vs. Katakana transcription of Kanji word) × 2 (Frequency: high vs. low) ANOVA on the orthographic familiarity ratings for Hiragana transcriptions produced no significant effects (all Fs < 1). The mean word frequency counts and orthographic familiarity ratings for the three types of scripts for each word group are listed in Table 3.[5]

Two sets of Katakana-word pairs were created based on the 60 selected Katakana words. The Katakana words were used as targets and paired with Hiragana primes. Half of the Katakana words were paired with their Hiragana transcriptions (repeated condition) in the first set and with Hiragana transcriptions of other target words (unrepeated condition) in the second set, and vice versa. The two sets consisted of the same Katakana targets but paired with different Hiragana primes.

Two sets of Katakana-transcription pairs were also created based on the 60 selected Kanji words. For these pairs, the Kanji words were transcribed into Katakana and used as targets. These words were paired with Hiragana primes in the same manner as with the Katakana-word pairs. The repeated Hiragana–Katakana pairs of 60 Katakana and 60 Kanji words are listed in Appendix B.

In addition, 120 Katakana nonwords were created from Kanji words. Kanji words were transcribed into Katakana and one of the Katakana characters was replaced with a different character to create a Katakana nonword. The syllabic lengths for these Katakana nonwords were matched with those of the 120 word stimuli. Mean syllabic length for these nonwords was 3.40, ranging from 3 to 4.

These Katakana nonwords were used as targets and paired with Hiragana primes. The 120 Katakana nonwords were divided into two sets of 60 nonwords. Based on each set of 60 nonwords, two sets of 60 nonword pairs (30 repeated and 30 unrepeated pairs) were created in the same manner as for the word pairs. Thus, four sets of 60 nonword pairs were created.

Based on the two sets of Katakana word pairs, the two sets of Katakana-transcription pairs, and the four sets of nonword pairs, the stimulus sets for the Katakana-word block were created by mixing a set of Katakana-word pairs with a set of nonword pairs. The stimulus sets for the Katakana-transcription block were also created by mixing a set of Katakana-transcription pairs with a set of nonword pairs. Because each participant received both Katakana-word and Katakana-transcription blocks, different sets of nonword pairs were used in the Katakana-word and Katakana-transcription blocks. Each block consisted of 120 trials, with 60 word target and 60 nonword target trials. No target appeared more than once for each participant. The combination of word and nonword pairs were counterbalanced. That is, four sets of nonword pairs were equally combined with four sets of word pairs across participants. Block order was also counterbalanced across participants. Half of the participants received the Katakana-word block first and the remainder of the participants received the Katakana-transcription block first.

Apparatus and procedure

Stimuli were presented on a video monitor (NEC, PC-TV455) driven by a 80386-based computer (NEC, PC-9801FA). Participants indicated the lexicality of stimuli (word or nonword) by pressing one of two keys on a computer keyboard. The two keys which flank the space-key were used as either the word or nonword key ("XFER" and "NFER" keys in a NEC Japanese keyboard). "Word" responses were made with the participants' dominant hand. The viewing distance was approximately 50 cm.

As in Experiment 1, a trial sequence consisted of a forward mask, a prime, and a target presentation. The forward mask consisted of a row of hash marks of the

[5] Although most of our stimuli are normally written in only one script, there were a few words that are also written in a second script. For these words, separate frequency counts are listed in the word frequency norms (National Language Research Institute, 1970) for the same words in different scripts. There were two words that are written in all three scripts and one word that is also written in Kanji in the high frequency Katakana word group. In the high frequency Kanji word group, there was one word that is also written in Hiragana.

Table 3
Mean word frequency (Freq.) and orthographic familiarity rating (FAM) for each script of the stimuli in each condition in Experiments 2, 3, and 4

Conditions	Script type					
	Kanji		Hiragana		Katakana	
Word type/frequency	Freq.	FAM	Freq.	FAM	Freq.	FAM
Kanji/low	5.77	5.15	0.00	2.55	0.00	2.25
Kanji/high	56.70	5.63	0.67	2.55	0.00	2.30
Katakana/low	0.00	—	0.00	2.54	6.20	5.11
Katakana/high	22.27	—	2.00	2.44	56.60	5.81

Note. Mean word frequencies and experiential familiarity ratings were not listed for Kanji script of the Katakana words because most of these words cannot be transcribed into Kanji.

same length as the prime and target. The forward mask was presented for 500 ms and was replaced by the Hiragana-written prime, which was presented for 32 ms and was immediately replaced by the Katakana-written target, which remained visible until the participant made a response. The onsets of the prime and target were, again, synchronized with the vertical retrace signals of the video monitor.

The experiment consisted of two blocks of trials—familiar Katakana-word target trials and unfamiliar Katakana-transcription target trials. In the familiar Katakana-word block, participants were instructed to decide whether the presented Katakana string was a word. In the unfamiliar Katakana-transcription block, participants were instructed to decide whether the presented Katakana string was a word transcribed into Katakana. Sixteen practice trials were given prior to each block. The practice trials preceding a Katakana-word block consisted of Katakana targets and Hiragana primes. The practice trials preceding the Katakana-transcription block consisted of Katakana targets and Hiragana primes. The order in which the trials were presented in each block was randomized separately for each participant. A rest period was provided after every 40 trials. In all other respects, the procedure was identical to that in Experiment 1.

Results

Lexical decision latencies less than 250 ms or greater than 1600 ms were classified as errors and excluded from the latency analyses. A total of 186 data points (3.23%) were excluded in this fashion. Mean lexical decision latencies of correct responses and mean error rates were calculated across participants and items separately. The mean lexical decision latencies and error rates averaged over the participants are presented in Table 4.

Subject and item means of lexical decision latencies and error rates for word trials were submitted to separate 2 (Script Familiarity: familiar Katakana-word block vs. unfamiliar Katakana-transcription block) × 2 (Frequency: high vs. low) × 2 (Repetition: repeated vs. unrepeated) ANOVAs. For the subjects' analyses, Script Familiarity, Frequency, and Repetition were all within-subject factors. For the items' analyses, Script Familiarity and Frequency were between-item factors, and Repetition was a within-item factor.

Word trials

In the analyses of lexical decision latencies, the main effect of Script Familiarity, $F_s(1,23) = 132.51$, $MSe = 18819.98$, $p < .001$; $F_i(1,116) = 258.11$, $MSe = 13173.36$, $p < .001$, and the main effect of Repetition, $F_s(1,23) = 30.17$, $MSe = 1608.97$, $p < .001$; $F_i(1,116) = 19.81$, $MSe = 3349.98, p < .001$, were significant in both the subjects' and the items' analyses. The main effect of Frequency was significant in the subjects' analysis, $F_s(1,23) = 17.85$, $MSe = 1760.13$, $p < .001$, and marginally significant in the items' analysis, $F_i(1,116) = 3.79$, $MSe = 13173.36$, $p < .06$.

More importantly, the interaction between Frequency and Script Familiarity was significant in both analyses, $F_s(1,23) = 24.48$, $MSe = 1704.91, p < .001$; $F_i(1,116) = 4.90$, $MSe = 13173.36$, $p < .05$. The interaction between Repetition and Script Familiarity was significant in the subjects' analysis, $F_s(1,23) = 5.86$, $MSe = 1863.15$, $p < .025$, and marginally significant in the items' analysis, $F_i(1,116) = 3.83$, $MSe = 3349.98$, $p < .06$. However, the interaction between Frequency and Repetition was not significant in either analysis, $F_s(1,23) = .00$, $MSe = 2306.39$; $F_i(1,116) = .04$, $MSe = 3349.98$, nor was the three-way interaction between Frequency, Repetition and Script Familiarity, $F_s(1,23) = .71$, $MSe = 997.09$; $F_i(1,116) = .13$, $MSe = 3349.98$.

To investigate the significant interaction between Repetition and Script Familiarity, planned comparisons were conducted to examine the difference between the repeated and unrepeated conditions for each target type by collapsing the Frequency factor. In the Katakana-word block, the 17 ms repetition priming effect was significant in both analyses, $t_s(23) = 2.00$, $p < .05$ one-tailed; $t_i(59) = 2.89$, $p < .001$ one-tailed. In the Katakana-transcription block, the 47 ms repetition priming effect was also significant in both analyses, $t_s(23) = 4.75$,

Table 4
Mean lexical decision latencies in milliseconds and error rates in percent in Experiment 2

Word type/frequency		Repetition		RT difference
		Repeated	Unrepeated	
Katakana word block (with familiar Katakana word targets)				
Katakana/high	RT	599 (79.71)	612 (80.15)	+13
	ER	1.95 (3.67)	2.78 (4.78)	
Katakana/low	RT	650 (107.33)	671 (73.31)	+21
	ER	5.83 (7.94)	10.00 (7.09)	
Nonword	RT	797 (169.82)	817 (205.69)	+20
	ER	8.06 (11.07)	7.50 (12.01)	
Katakana transcription block (with unfamiliar Katakana transcription targets)				
Kanji/high	RT	837 (118.53)	888 (118.96)	+51
	ER	19.17 (14.08)	18.33 (9.27)	
Kanji/low	RT	837 (116.10)	880 (122.47)	+43
	ER	20.56 (14.70)	25.56 (12.99)	
Nonword	RT	967 (160.19)	975 (160.02)	+8
	ER	12.36 (10.52)	13.33 (8.96)	

Note. RT and ER stand for mean reaction time and error rate, respectively. Standard deviation is in parenthesis.

$p < .001$ one-tailed; $t_i(59) = 3.58$, $p < .001$ one-tailed. Thus, the Repetition by Script Familiarity interaction reflects the fact that the repetition priming effect was smaller for familiar Katakana-word targets than for unfamiliar Katakana-transcription targets.

Similarly, planned comparisons were also conducted to examine the differences between the high and the low frequency conditions for each target type by collapsing the Repetition factor. In the Katakana-word block, the 55 ms difference between the high and low frequency conditions was significant in both analyses, $t_s(23) = 8.66$, $p < .001$ one-tailed; $t_i(58) = 4.18$, $p < .001$ one-tailed, whereas the 4 ms difference in the Katakana-transcription block was not significant in either analysis, $t_s(23) = .45$ one-tailed; $t_i(58) = .17$ one-tailed. Thus, the significant Frequency by Script Familiarity interaction reflects the fact that the frequency effect was limited to familiar Katakana-word targets.

In the analyses of error rates, the main effect of Script Familiarity was significant in both analyses, $F_s(1,23) = 106.90$, $MSe = 111.59$, $p < .001$; $F_i(1,116) = 38.94$, $MSe = 382.87$, $p < .001$. The main effect of Frequency was significant in the subjects' analysis, $F_s(1,23) = 18.10$, $MSe = 64.47$, $p < .001$, and marginally significant in the items' analysis, $F_i(1,116) = 3.81$, $MSe = 382.87$, $p < .06$. The main effect of Repetition was significant in the items' analysis, $F_i(1,116) = 4.05$, $MSe = 77.86$, $p < .05$, and marginally significant in the subjects' analysis, $F_s(1,23) = 3.07$, $MSe = 82.04$, $p < .10$.

The interaction between Frequency and Repetition was significant in both analyses, $F_s(1,23) = 5.94$, $MSe = 42.41$, $p < .025$; $F_i(1,116) = 4.05$, $MSe = 77.86$, $p < .05$. The interaction between Repetition and Script Familiarity, $F_s(1,23) = .03$, $MSe = 71.63$; $F_i(1,116) = .03$, $MSe = 77.86$, and the interaction between Frequency and Script Familiarity, $F_s(1,23) = .25$, $MSe = 75.74$; $F_i(1,116) = .06$, $MSe = 382.87$, were not significant in either analysis, nor was the three-way interaction between Frequency, Repetition, and Script Familiarity, $F_s(1,23) = .20$, $MSe = 95.07$; $F_i(1,116) = .30$, $MSe = 77.86$.

Nonword trials

For nonword trials, subject and item means of lexical decision latencies and error rates were submitted to separate 2 (Script Familiarity: familiar Katakana word block vs. unfamiliar Katakana transcription block) × 2 (Repetition: repeated vs. unrepeated) ANOVAs. For the subjects' analyses, Script Familiarity and Repetition were within-subject factors. For the items' analyses, they were within-item factors. It should be noted that, for the nonwords, the Script Familiarity factor refers only to the word context in which the nonwords were presented. That is, unlike with the words, the nonwords cannot be classified as to whether they themselves were presented in a familiar script or in an unfamiliar script.

In the analyses of lexical decision latencies, the main effect of Script Familiarity was significant in both analyses, $F_s(1,23) = 36.81$, $MSe = 17650.54$, $p < .001$; $F_i(1,119) = 289.51$, $MSe = 12890.53$, $p < .001$. Participants responded faster on nonword trials when the word targets were Katakana words. The main effect of Repetition was marginally significant in the subjects' analysis, $F_s(1,23) = 3.84$, $MSe = 1241.38$, $p < .07$, although it was not significant in the items' analysis, $F_i(1,119) = 1.99$, $MSe = 6975.44$. The interaction between Repetition and

Script Familiarity was not significant in either analysis, $F_s(1,23) = .79$, $MSe = 1167.58$; $F_i(1,119) = .11$, $MSe = 6874.28$.

In the analyses of error rates, the main effect of Script Familiarity was significant in both analyses, $F_s(1,23) = 7.04$, $MSe = 87.57, p < .025$; $F_i(1,119) = 14.90$, $MSe = 206.93$, $p < .001$. Participants were more accurate on nonword trials when the word targets were Katakana words. The main effect of Repetition was not significant in either analysis, $F_s(1,23) = .05$, $MSe = 19.16$; $F_i(1, 119) = .05$, $MSe = 113.76$, nor was the interaction between Repetition and Script Familiarity, $F_s(1,23) = 1.19$, $MSe = 11.83$; $F_i(1,119) = .58$, $MSe = 120.21$.

Discussion

Cross-script masked repetition priming effects were, again, observed only for word targets on lexical decision latencies and error rates. Further, as in Experiment 1, the masked repetition priming effects were virtually identical for high frequency and low frequency words in the latency data for both familiar Katakana-word targets and unfamiliar Katakana-transcription targets although, in the error data, the effects were again somewhat larger for low frequency targets than for high frequency targets. Thus, these data once again mirror the patterns reported by Forster and Davis (1984).

In addition, as in Experiment 1, there was a Repetition by Script Familiarity interaction. The cross-script masked repetition priming effects were larger for the unfamiliar Katakana-transcription targets than for the familiar Katakana-word targets. In the present experiment, we equated the orthographic familiarity ratings of Hiragana-written primes between the two blocks, so that it is unlikely that the difference in the sizes of repetition priming effects was due to processing differences between the prime stimuli in the two blocks. Further, we used the same nonwords in the two blocks. Thus, the effect size difference also cannot be explained in terms of the nonwords used. The most straightforward conclusion, therefore, seems to be that repetition priming effects are larger for words written in an unfamiliar script than for words written in a familiar script, a conclusion that is consistent with the predictions of the phonological activation account.

Finally, significant word frequency effects were observed only for the familiar Katakana-word targets in the latency data. That is, when Katakana transcriptions of high and low frequency Kanji words were matched on orthographic familiarity, the word frequency of the original Kanji words appeared to have no effect on lexical decision latencies for their Katakana transcriptions.

According to classical lexical models, lexical-decision making requires lexical selection to be completed. The lexical-selection process would typically be more orthographically based when words were presented in their familiar script (e.g., Besner & Hildebrandt, 1987), whereas it would have to be driven by phonological units for the Katakana transcriptions. If we further assume that the lexical-selection process is frequency sensitive, we should have observed significant word frequency effects, even for the Katakana transcriptions. As such, the lack of a frequency effect for the unfamiliar Katakana transcriptions is problematic for these types of models. That is, regardless of whether the masked repetition priming effects are due to lexical activation or phonological activation, the types of lexical models we have been considering (i.e., models in which frequency sensitivity is essentially a component of the lexical units themselves) are unable to account for these results.

Given the somewhat large error rates, however, especially for low frequency words in the Katakana-transcription condition, one could argue that any frequency effects for these stimuli might be somewhat difficult to find. To address this issue, we divided our participants into two groups based on their total error rates. Collapsing over the repetition factor, the mean error rates for the high and low frequency Katakana transcriptions were 16.39 and 19.45% in the lower error rate group and 21.11 and 26.67% in the higher error rate group, respectively. There was no sign of a frequency effect in either group in the latency data (a nonsignificant 8 ms effect in the lower error rate group and a nonsignificant −16 ms effect in the higher error rate group). As such, it seems unlikely that the lack of a frequency effect for the Katakana transcriptions was simply due to the larger error rates in the low frequency condition for these stimuli. We will return to this issue in Experiment 4.

This complete lack of a frequency effect for the Katakana transcriptions is, perhaps, surprising to many readers and, hence, requires a bit more discussion. One important difference between the Katakana transcriptions and the Katakana words, of course, is that we selected our high and low frequency Kanji words so that their transcriptions were matched on orthographic familiarity ratings. Our reason for doing so was to prevent participants from using orthographic familiarity as a cue in lexical-decision making. What we cannot know for certain, of course, is whether the orthographic familiarity ratings our participants gave us reflected *only* orthographic familiarity or whether they also reflected some other factor(s) (see Balota, Pilotti, & Cortese, 2001 for a discussion of these issues). If they did reflect some other factor(s), then, it might be possible to explain the lack of a frequency effect in terms of that factor(s).

Suppose, for the moment, that our participants were, in part, basing their ratings on a factor (or factors) other than orthographic familiarity. Suppose also that that factor is theoretically relevant to the lexical-selection process in classical lexical models. Finally, suppose that the selected stimuli showed a negative correlation between that factor and frequency. Under these circumstances, it would be quite possible that, due to the negative correlation between the other factor and frequency, the other factor could have killed the frequency effect. More concretely, suppose that participants were using orthographic neighborhood size in their orthographic familiarity ratings with words having a larger neighborhood size receiving higher familiarity ratings. To select high and low frequency stimuli that were equivalent on rated orthographic familiarity, by necessity, we would have ended up with a set of the low frequency words that had, on average, a larger neighborhood size than the high frequency words. As a result, the neighborhood size effect would have potentially cancelled out our frequency effect.

Could something of this sort have happened here? As noted, our high and low frequency transcriptions were equated on orthographic neighborhood size. However, it is not impossible that there was some other theoretically relevant factor that was negatively correlated with frequency among our selected stimuli. Note that if that factor is a semantic factor (e.g., ambiguity, concreteness), it should also affect the size of the frequency effect when these words are presented in their original Kanji forms. Thus, there should also be little evidence of a frequency effect when these words are presented in their Kanji forms. We will return to this issue in Experiment 4.

What if this unknown factor was a phonological factor? For example, suppose that participants were considering how difficult it is to generate a phonological code when making these judgments. Suppose also that this is typically easier for high frequency words so that, in general, high frequency words receive higher orthographic familiarity ratings. To select high and low frequency words that were equivalent on rated orthographic familiarity, therefore, by necessity, we would have ended up with a set of low frequency words for which it was easier to generate a phonological code than for our set of high frequency words. If ease of generation of the phonological code also affects latency in this task, then it is quite possible that an "ease of generation effect" would have cancelled out the frequency effect.[6]

This type of argument makes an obvious prediction. If it is easier to generate phonological codes for our selected low frequency words than for our selected high frequency words, we should observe a reversed frequency effect in a naming task. This is one of the issues addressed in Experiment 3.

The inability of a model postulating abstract, frequency-sensitive lexical units to explain the lack of a frequency effect (without claiming that it was due to a confound) raises an obvious question. Would it be possible to explain these results if some nonessential assumptions of the model were altered? For example, we have been working under the assumption that frequency sensitivity was essentially a component of the lexical units themselves. That is, as proposed by classical lexical models, we have been assuming that word frequency determines either the resting activation level of the lexical unit or its position in the search process. Thus, any time a lexical unit is selected, there should be evidence of frequency effects. In contrast, some researchers have suggested that word frequency is coded in links between units rather than in the units themselves (e.g., Besner & Smith, 1992; McCann & Besner, 1987; McCann et al., 1988). That is, according to this type of argument, what is frequency sensitive is not the lexical units themselves but the linkages between the sublexical units and the lexical units.

In this type of conceptualization, the speed of lexical selection would be modulated by the frequency with which those specific sublexical codes had successfully selected that lexical unit in the past. If so, word frequency effects may arise only when words are presented in their familiar script and, hence, only when lexical selection is driven by the typical orthographic units. When words are presented in an unfamiliar script, however, frequency effects would be minimal because this process would be driven by phonological units that are being generated based on novel character strings. As such, the lack of a frequency effect for the Katakana transcriptions in Experiment 2 could be accommodated within a model postulating abstract lexical units. Therefore, if the lexical and phonological activation accounts are mapped onto this amended lexical model, both accounts can explain the Frequency by Script Familiarity interaction in Experiment 2.

In addition, the lexical activation account (when mapped onto this amended lexical model) could now explain the Repetition by Script Familiarity interaction. According to this account, an activated lexical unit facilitates the lexical-selection process regardless of how that process was being accomplished (e.g., via orthographic or via phonological codes). More importantly, one could easily argue that the slower lexical selection based on phonological codes should produce larger levels of facilitation than the faster lexical selection based on familiar orthographic codes (e.g., as when Katakana words themselves are presented). Thus, we are once again in a situation where both the lexical and phonological activation accounts are viable if both of these accounts incorporate the assumption that the linkages between sublexical and lexical units, not the lexical units themselves, are frequency sensitive. Experiment 3 was an attempt to further discriminate between these alternatives by examining cross-script masked repetition priming effects for nonword targets using a naming task.

[6] We thank an anonymous reviewer for suggesting this possibility.

Experiment 3

Although both the lexical and phonological activation accounts can be modified to account for the results of Experiments 1 and 2, these accounts make further specific predictions with respect to masked repetition priming effects for nonword targets. If the cross-script repetition priming effects are produced by the activation of abstract lexical units shared by primes and targets, these effects should be limited to targets that require lexical selection (e.g., words presented in their familiar script). On the other hand, if the repetition priming effects are produced by activated phonological units, the effects would be expected for all targets, both words and nonwords.

Note that the question of masked repetition priming of nonword targets has already been addressed in the present experiments. For example, in Experiment 2, primes and targets (both words and nonwords) were presented in Kana scripts, shallow orthographies with regular character-to-sound relationships. No priming effects were observed for these nonword targets. If the cross-script repetition priming effects were mediated by phonological units, repetition priming effects would have been expected not only for word targets but also for nonword targets. As originally argued by Forster and Davis (1984), however, our (and their) failure to observe masked repetition priming effects for nonwords appears to provide evidence in favor of a lexical activation account and against any nonlexical (e.g., phonologically based) account of repetition priming.

Bodner and Masson (1997) have argued, however, that masked repetition priming effects for nonword targets in lexical decision tasks are often quite difficult to detect because whatever processing advantage those stimuli would receive during early stages of processing would inevitably be canceled at the decision-making stage (during which this facilitation would create a "word" bias). Specifically, what Bodner and Masson suggested is that masked repetition primes would facilitate the construction of abstract orthographic representations prior to lexical selection. Whenever the construction of orthographic representations is facilitated in this fashion, it would create increased perceptual fluency which would increase the familiarity value calculated for that target stimulus. As a consequence, participants would be biased to make "word" decisions during the decision-making process. Thus, for word targets, repetition priming effects would be produced due both to the facilitation during orthographic processing and to the "word" bias during the decision-making process. To make correct "nonword" decisions for repeated nonwords, however, extra time would be required to overcome this "word" bias. Thus, any benefit of repetition priming for nonword targets during orthographic processing would be counteracted and, hence, difficult to detect.

Note that Bodner and Masson's (1997) account is based on the idea that what is being facilitated in masked repetition priming experiments is the construction of orthographic representations. As noted earlier, because there is little orthographic similarity between the different Japanese scripts, different orthographic representations would be generated by our primes and targets even in the repetition condition. Thus, if Bodner and Masson are correct, there should be no cross-script masked repetition priming effects for either word targets or nonword targets in our experiments. However, their point about the difficulty of observing repetition priming effects for nonwords in lexical decision is well-taken. Further, as Masson and Isaak (1999) suggest, Bodner and Masson's explanation could be rephrased in terms of phonological representations (see also Lukatela & Turvey, 1994). (And such an account could essentially become the phonological activation account discussed here.) If it were, it would appear to provide an explanation for the lack of significant repetition priming effects for nonword targets in our lexical decision experiments. Therefore, the lack of masked repetition priming effects for nonwords in our lexical decision experiments would not necessarily be inconsistent with an account of cross-script repetition priming effects based on phonological codes.

Masson and Isaak (1999) have suggested that masked repetition priming effects for nonwords, if they do exist, should be more easily detectable in a naming task because this task does not involve a decision-making process. In fact, as previously noted, Masson and Isaak did obtain significant masked repetition priming effects not only for word targets but also for nonword targets in their naming experiment. Consequently, in Experiment 3, we attempted to test our two amended accounts by examining cross-script masked repetition priming effects for nonwords using a naming task. If the lexical activation account is correct, we would expect to find masked repetition priming effects only for words that are named lexically (i.e., those presented in a familiar script). If the masked repetition priming effects are due to phonological activation, however, we would expect to find those effects for both words and nonwords.

Note also that both accounts predict frequency effects only for words presented in a familiar script because only those words are named lexically. Finally, as discussed above, the existence or nonexistence of a frequency effect for the transcriptions in naming has implications for theorizing about the lack of a frequency effect for transcriptions in lexical decision. That is, it is possible that the reason there was no frequency effect for transcriptions in Experiment 2 was that it was actually easier to generate phonological codes for the selected low frequency words than for the selected high frequency words. If this is the case, the expectation is that those same transcription targets will show a reverse frequency effect in Experiment 3.

Method

Participants

Twenty-four undergraduate students from Chukyo University participated in this experiment for course credit. All were native Japanese speakers who had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli

The word stimuli were the two sets of Katakana transcription (of Kanji word) pairs and the two sets of Katakana word pairs used in Experiment 2. In addition, 60 of the nonwords used in Experiment 2 were selected and divided into two sets of 30 nonwords. In the same manner as in Experiment 2, four sets of nonword pairs were created, each of which consisted of 15 repeated and 15 unrepeated pairs.

Forster and Davis (1991) reported that interference is produced in naming tasks (but not in lexical decision tasks) if (masked) primes and targets have different onsets. To eliminate contamination from this "onset effect," all the unrepeated primes were replaced with new items having the same initial character (thus, the same initial syllable (mora)) as their targets (although they were written in a different script). These unrepeated primes and targets consisted of different characters in other character positions, however.

In the same manner as in Experiment 2, a set of word pairs and a set of nonword pairs were combined to create stimulus sets for the familiar Katakana-word block and the unfamiliar Katakana-transcription block, respectively. Thus, each block consisted of 60 word target and 30 nonword target trials.

Apparatus and procedure

The apparatus and the procedure were identical to those in Experiment 2 with following exceptions. Participants were asked to name a Katakana character string aloud appearing on the video monitor as quickly and as accurately as possible. Participants' vocal responses were registered by a microphone connected to a voice key interfaced to the computer. The vocal response terminated the stimulus presentation. Naming latency was measured from the onset of the target to the onset of the response. An experimenter was in a different room but was able to check the participants' vocal responses through audio/video monitors and record errors. As in Experiment 2, this experiment consisted of Katakana-word and Katakana-transcription blocks presented in a counterbalanced order. Each block consisted of 90 trials. Twelve practice trials were given prior to each block.

Results

A trial was considered a mechanical error if the participant's vocal response failed to trigger the voice key or some extraneous sound triggered the voice key. There were 11 mechanical errors (0.25%) in total. The mechanical errors were excluded from the data analyses. In addition, naming latencies less than 250 ms or greater than 1200 ms were classified as errors and excluded from the latency analyses. A total of 16 data points (0.37%) were excluded in this fashion. Mean naming latencies of correct responses and mean error rates were calculated across participants and items separately. The mean naming latencies and error rates averaged over the participants are presented in Table 5.

Nonword trials

For nonword trials, subject and item means of naming latencies and error rates were submitted to separate 2 (Script Familiarity) × 2 (Repetition) ANOVAs as in Experiment 2. As in Experiment 2, in the nonword analysis, the script familiarity factor refers only to the word context in which the nonwords were presented.

In the analyses of naming latencies, the main effect of Repetition was significant in both analyses, $F_s(1,23) = 10.03$, $MSe = 767.72$, $p < .01$; $F_i(1,59) = 5.92$, $MSe = 2312.64$, $p < .025$. However, neither the main effect of Script Familiarity, $F_s(1,23) = .54$, $MSe = 2418.95$; $F_i(1,59) = 1.88$, $MSe = 1714.89$; nor the interaction between Repetition and Script Familiarity, $F_s(1,23) = .12$, $MSe = 643.19$; $F_i(1,59) = .00$, $MSe = 4177.89$, was significant in either analysis. In the analyses of error rates, neither of the main effects nor the interaction approached significance in either analysis (all $F_s < 1.30$).

Word trials

As in Experiment 2, subject and item means of naming latencies and error rates for word trials were submitted to separate 2 (Script Familiarity) × 2 (Frequency) × 2 (Repetition) ANOVAs. In the analyses of naming latencies, the main effect of Script Familiarity was significant in both the subjects' and the items' analyses, $F_s(1,23) = 91.68$, $MSe = 1772.39$, $p < .001$; $F_i(1,116) = 72.82$, $MSe = 2808.60$, $p < .001$. The main effect of Repetition was also significant in both analyses, $F_s(1,23) = 24.95$, $MSe = 549.15$, $p < .001$; $F_i(1,116) = 29.26$, $MSe = 527.27$, $p < .001$. The main effect of Frequency was significant in the subjects' analysis, $F_s(1,23) = 15.56$, $MSe = 231.37$, $p < .01$, although not in the items' analysis, $F_i(1,116) = 1.87$, $MSe = 2808.60$.

The interaction between Frequency and Script Familiarity was significant in the subjects' analysis, $F_s(1,23) = 10.86$, $MSe = 260.78$, $p < .01$, although not in the items' analysis, $F_i(1,116) = 1.12$, $MSe = 2808.60$. The interaction between Repetition and Script Familiarity, $F_s(1,23) = 1.06$, $MSe = 333.11$; $F_i(1,116) = .66$, $MSe = 527.27$, and the interaction between Frequency and Repetition, $F_s(1,23) = .39$, $MSe = 371.46$; $F_i(1,116) = .07$, $MSe = 527.27$, were not significant in either analysis, nor was the three-way interaction between

Table 5
Mean naming latencies in milliseconds and error rates in percent in Experiment 3

Word type/frequency		Repetition		RT difference
		Repeated	Unrepeated	
Katakana word block (with familiar Katakana word targets)				
Katakana/high	RT	480 (47.01)	497 (52.80)	+17
	ER	1.11 (2.54)	0.83 (2.25)	
Katakana/low	RT	499 (49.07)	510 (52.19)	+11
	ER	1.69 (2.99)	1.67 (3.54)	
Nonword	RT	572 (90.35)	592 (80.62)	+20
	ER	8.35 (6.88)	10.67 (11.24)	
Katakana transcription block (with unfamiliar Katakana transcription targets)				
Kanji/high	RT	544 (63.37)	564 (68.84)	+20
	ER	2.22 (3.21)	6.17 (7.64)	
Kanji/low	RT	546 (65.41)	565 (63.46)	+19
	ER	3.06 (4.39)	4.45 (4.68)	
Nonword	RT	581 (82.83)	597 (76.64)	+16
	ER	9.45 (9.61)	9.72 (9.42)	

Note. RT and ER stand for mean reaction time and error rate, respectively. Standard deviation is in parenthesis.

Frequency, Repetition, and Script Familiarity, $F_s(1,23) = .16$, $MSe = 364.46$; $F_i(1,116) = .68$, $MSe = 527.27$.

To examine the significant interaction between Frequency and Script Familiarity, planned comparisons were conducted contrasting the difference between the high and low frequency conditions for each target type by collapsing across the Repetition factor. The 16 ms difference between the high and low frequency words in the Katakana-word block was significant in both analyses, $t_s(23) = 8.33, p < .001$ one-tailed; $t_i(58) = 2.05, p < .025$ one-tailed, whereas the 2 ms difference in the Katakana-transcription block was not significant in either analysis, $t_s(23) = .35$ one-tailed; $t_i(58) = .14$ one-tailed. As such, the significant interaction between Frequency and Script Familiarity reflects the fact that a frequency effect existed only for familiar Katakana-word targets.

In the analyses of error rates, the main effect of Script Familiarity was significant in both analyses, $F_s(1,23) = 23.03$, $MSe = 14.63$, $p < .001$; $F_i(1,116) = 10.41$, $MSe = 40.72$, $p < .01$. The main effect of Repetition was also significant in both analyses, $F_s(1,23) = 5.36$, $MSe = 14.22, p < .05; F_i(1,116) = 5.30$, $MSe = 18.24, p < .025$. The main effect of Frequency was not significant in either analysis, $F_s(1,23) = .06$, $MSe = 13.51$; $F_i(1,116) = .86$, $MSe = 40.72$.

The interaction between Repetition and Script Familiarity was significant in both analyses, $F_s(1,23) = 6.16$, $MSe = 15.47$, $p < .025$; $F_i(1,116) = 6.52$, $MSe = 18.24, p < .025$. The interaction between Frequency and Script Familiarity, $F_s(1,23) = .94$, $MSe = 16.85$; $F_i(1,116) = .49$, $MSe = 40.72$, and the interaction between Frequency and Repetition, $F_s(1,23) = 1.06$, $MSe = 15.06$; $F_i(1,116) = 1.09$, $MSe = 18.24$, were not significant in either analysis, nor was the three-way interaction between Frequency, Repetition, and Script Familiarity, $F_s(1,23) = 1.88$, $MSe = 12.64; F_i(1,116) = 1.67$, $MSe = 18.24$.

To examine the significant interaction between Repetition and Script Familiarity, planned comparisons were conducted contrasting the difference between the repeated and unrepeated conditions for each target type by collapsing across the Frequency factor. In the Katakana-transcription block, fewer errors were observed in the repeated condition than in the unrepeated condition. The difference between the two conditions was significant in both analyses, $t_s(23) = 2.62$, $p < .01$ one-tailed; $t_i(59) = 2.67\ p < .01$ one-tailed. In the Katakana-word block, however, the difference between the two conditions was not significant in either analysis, $t_s(23) = -.31$ one-tailed; $t_i(59) = -.30$ one-tailed. Thus, the Repetition by Script Familiarity interaction reflects the fact that a repetition priming effect was observed only for unfamiliar Katakana transcription targets.

Comparisons of repetition priming effects for words and nonwords

To further compare the masked repetition priming effect sizes for words and nonwords, subject and item means of naming latencies were submitted to separate 2 (Script Familiarity) × 2 (Repetition) × 2 (Lexicality: Words vs. Nonwords) ANOVAs with the Frequency factor collapsed for word targets.

The main effects of Script Familiarity, $F_s(1,23) = 20.83$, $MSe = 2482.44$, $p < .001$; $F_i(1,236) = 27.44$, $MSe = 4719.21$, $p < .001$, Repetition, $F_s(1,23) = 28.39$, $MSe = 515.44$, $p < .001$; $F_i(1,236) = 15.45, MSe =$

1883.47, $p < .001$, and Lexicality, $F_s(1,23) = 96.50$, $MSe = 1971.59$, $p < .001$; $F_i(1,236) = 101.93$, $MSe = 4719.21$, $p < .001$, were all significant in both the subjects' and items' analyses. The Lexicality by Script Familiarity interaction was also significant in both analyses, $F_s(1, 23) = 37.46$, $MSe = 831.15$, $p < .001$; $F_i(1,236) = 16.58$, $MSe = 4719.21$, $p < .001$. But neither the Repetition by Script Familiarity interaction, nor the Lexicality by Repetition interaction, nor the three-way interaction between Lexicality, Repetition, and Script Familiarity was significant in either analysis, all Fs $< .50$. The lack of a significant interaction between Lexicality and Repetition reflects the fact that masked repetition priming effect sizes were similar for words and nonwords.

To examine the significant Lexicality by Script Familiarity interaction, planned comparisons were conducted contrasting the lexicality effects for each target type by collapsing the Repetition factor. In the Katakana word block, the 86 ms lexicality effect was significant in both analyses, $t_s(23) = 9.77$, $p < .001$ one-tailed; $t_i(118) = 10.67$, $p < .001$ one-tailed. In the Katakana transcription block, the 35 ms lexicality effect was also significant in both analyses, $t_s(23) = 5.71$, $p < .001$ one-tailed; $t_i(118) = 4.09$, $p < .001$ one-tailed. As such, the Lexicality by Script Familiarity interaction reflects the fact that the lexicality effect was larger in the Katakana-word block than in the Katakana-transcription block.

Discussion

Paralleling the results of the two previous experiments, significant cross-script masked repetition priming effects were observed in a naming task and these effects were essentially the same size for high and low frequency words. In addition, paralleling the lexical decision results of Experiment 2, significant word frequency effects were observed only for the familiar Katakana word targets in the analysis of naming latencies. Most importantly, however, unlike in the previous experiments, repetition priming effects were observed for nonwords. In fact, the sizes of the priming effects were essentially identical for nonwords, familiar script words and unfamiliar script words. Finally, consistent with Besner and Hildebrandt's (1987) data, naming responses were faster for word targets than for nonword targets even in the unfamiliar Katakana-transcription block, although the word-nonword difference in that block was smaller than in the familiar Katakana-word block.

The results for the Katakana transcriptions are actually quite similar to those reported by McCann and Besner (1987) using English stimuli. McCann and Besner examined base-word frequency effects in the naming of pseudohomophones (see also Besner, 1999, for a review). As previously noted, pseudohomophones are nonwords which, when pronounced, sound like real words. Because pseudohomophones possess novel orthographic patterns, they are similar to Katakana transcriptions of Kanji words like those used in our experiments, although Japanese readers classify these Katakana transcriptions as words.

In their naming experiment, McCann and Besner (1987) failed to observe a significant base-word frequency effect in the naming of pseudohomophones, although naming latencies for pseudohomophones were faster than those for pronounceable nonwords, paralleling the present results. Because of the pseudohomophone advantage, McCann and Besner suggested that pseudohomophone naming was guided by lexical information. That is, they argued that there was some interaction between phonological units and lexical units and that that interaction facilitated either the phonological coding process or the articulatory code generation process (or both) for pseudohomophones but not for pronounceable nonwords. However, because of the lack of a base-word frequency effect, McCann and Besner also argued that the lexical units themselves are not frequency sensitive. Rather, in line with the amended models considered here, it is the links between representational units that are assumed to be frequency sensitive (see also Plourde & Besner, 1997).

Following McCann and Besner's (1987) arguments, therefore, the faster latencies for words in both the familiar and unfamiliar script blocks can be taken to mean that lexical information was involved in the naming of word targets even when they appeared in an unfamiliar script. Therefore, according to the lexical activation account, masked repetition priming effects would be expected for both types of word targets, as was observed. The problem for this account, however, is that significant masked repetition priming effects were also observed for nonword targets. According to the lexical activation account, it should not be possible to observe cross-script masked repetition priming of nonwords because they would not benefit from lexical activation. Further, as previously noted, it would not be possible to explain those effects in terms of priming at the orthographic level (as done by Bodner & Masson, 1997) because there is little orthographic similarity between different Japanese scripts.

In contrast, the amended phonological activation account is consistent with the present results. That is, this account can explain the similar size masked repetition priming effects for nonword targets and both types of word targets. In addition, the lack of a frequency effect and the smaller but still significant lexicality effect for the unfamiliar transcription targets could also be explained essentially using McCann and Besner's (1987) analysis. As such, based on the present data, this account appears to be a better explanation of masked repetition priming than the lexical activation account.

Finally, note also that there was not a reverse frequency effect for the transcriptions. This result indicates that it was not easier to generate phonological codes from the selected low frequency words than from the selected high frequency words. Thus, an explanation based on this premise does not appear to be a good explanation of the lack of a frequency effect in Experiment 2.

Experiment 4

As discussed earlier, the fact that there were essentially no word frequency effects for the unfamiliar Katakana transcriptions of Kanji words in Experiment 2 is clearly a problem for classical lexical models. In the classical lexical models, frequency is supposed to be encoded in the lexical units and, thus, regardless of how those units are accessed, frequency effects should emerge. However, this lack of an effect for the transcriptions is only problematic if there actually are frequency effects for the original Kanji words. If those words do not show frequency effects, it would indicate either: (a) that the lexical units for those words had fairly equivalent frequency sensitivities even though the words themselves had different frequencies in the language or (b) that there was a theoretically relevant variable (e.g., ambiguity, concreteness) that was negatively correlated with frequency among our stimuli (see Borowsky & Masson, 1999, for a similar argument). To address this potential criticism, we conducted single item lexical decision and naming tasks using the 60 original Kanji words which were used to generate the unfamiliar Katakana-transcription targets in Experiments 2 and 3.

In addition, as previously noted, the error rates for the Katakana-transcription targets were fairly high, especially for low frequency words, in the lexical decision task of Experiment 2. Thus, there is the possibility that any existing frequency effect for these Katakana transcriptions may be undetected in the latency data due to the higher error rates. To address this issue, we also conducted a single item lexical decision task for the 60 Katakana transcriptions.

Further, it may be possible to argue that the lack of a frequency effect for the Katakana transcriptions in the naming task of Experiment 3 was due to the fact that the stimulus set involved nonwords. For example, Baluch and Besner (1991), Hudson and Bergman (1985), and Tabossi and Laghi (1992) reported that word frequency and semantic priming effects, which were significant when the stimulus set consisted only of words, disappeared when the stimulus set involved nonwords, at least when using shallow orthographies such as Dutch and Italian as well as phonologically transparent words (in which vowels are specified with vowel letters and diacritics) in Persian. Because Katakana is also a shallow script, one could also make the same argument here. If so, it may be possible that the Katakana transcriptions would produce a significant frequency effect when nonwords were not included in the stimulus set. To address this issue, we also conducted a single item naming task using these Katakana transcriptions.

Method

Participants

One hundred and six undergraduate students from Chukyo University participated in this experiment for course credit. Four tasks (a lexical decision task with Kanji words, a lexical decision task with Katakana transcriptions, a naming task with Kanji words, and a naming task with Katakana transcriptions) were separately conducted. Thirty-four students participated in the lexical decision task with Katakana transcriptions. Twenty-four students participated in each of the other three tasks. All were native Japanese speakers who had normal or corrected-to-normal vision. None had participated in any of the previous experiments.

Stimuli

The word stimuli were either the 30 high and 30 low frequency original Kanji words which were used to create the unfamiliar Katakana transcription targets by transcribing them into Katakana in Experiments 2 and 3 or the Katakana transcriptions themselves. In the two naming tasks, the stimulus sets consisted only of word stimuli (either the 60 Kanji words or the 60 Katakana transcriptions). Sixty Kanji nonwords were created by combining two Kanji characters which have only a single pronunciation and were used in the lexical decision task with the Kanji words. In the lexical decision task with the Katakana transcriptions, 60 Katakana nonwords were used, which were transcribed from those Kanji nonwords. In both lexical decision tasks, the syllabic lengths for these nonwords were matched with those of the Kanji words.

Apparatus and procedure

In the lexical decision tasks, the apparatus was the same as that in Experiment 2. Participants in the lexical decision tasks were asked to make a lexical decision to a character string appearing on the video monitor by pressing either the "Word" or "Nonword" key on the computer keyboard. In the naming tasks, the apparatus was the same as that in Experiment 3. Participants were asked to name a word aloud into the microphone when it appeared on the video monitor.

In each task, a trial was initiated with a 50 ms 400 Hz beep signal. Following the beep, a fixation point appeared at the center of the video monitor. One second after the onset of the fixation point, a stimulus was presented above the fixation point. Participants were required to respond to the stimulus as quickly and as accurately as possible. The participant's response terminated the presentation of the stimulus and the fixation point. In the lexical decision tasks, lexical decision latency from the onset of the stimulus to the participant's key press and whether the response was correct were automatically recorded by the computer. In the naming tasks, naming latency was measured from the onset of the stimulus to the onset of the vocal response. An experimenter checked the participants' responses from a different room through audio/video monitors and recorded errors. In each task, 16 practice trials were given prior to the experimental trials. The intertrial interval was two seconds.

Results

Lexical decision task with Kanji words

Lexical decision latencies less than 250 ms or greater than 1600 ms were classified as errors and excluded from the latency analyses. A total of 12 data points (0.42%) were excluded in this fashion. Mean lexical decision latencies for correct responses and mean error rates were calculated across participants and items separately. The mean lexical decision latencies and error rates from the subjects' analysis are presented in Table 6.

In the analyses of lexical decision latencies, the 39 ms frequency effect was significant both in the subjects' and items' analyses, $t_s(23) = 5.75$, $p < .001$; $t_i(58) = 2.64$, $p < .025$. In the analyses of error rates, the 7.09% frequency effect was also significant in both analyses, $t_s(23) = 4.02$, $p < .025$; $t_i(58) = 2.44$, $p < .025$.

Lexical decision task with Katakana transcriptions

Lexical decision latencies less than 250 ms or greater than 1600 ms were classified as errors and excluded from the latency analyses. There were 10 participants whose error rate was greater than 20%. These participants' data were excluded from the analyses. Thus, the analyses were conducted on the remaining 24 participants' data. In these data, a total of 50 data points (1.74%) were classified as errors due to the cutoff criteria noted above. Mean lexical decision latencies for correct responses and mean error rates were calculated across participants and items separately. The mean lexical decision latencies and error rates from the subjects' analysis are presented in Table 6.

In the analyses of lexical decision latencies, the 7 ms frequency effect was not significant in either analysis, $t_s(23) = 1.05$; $t_i(58) = .04$. In the analyses of error rates, the 3.33% frequency effect was significant in the subjects' analysis, $t_s(23) = 2.85$, $p < .01$, although not in the items' analysis, $t_i(58) = .64$.

Naming task with Kanji words

A trial was considered a mechanical error if the participant's vocal response failed to trigger the voice key or if an extraneous sound triggered the voice key. There were 7 mechanical errors (0.49%) in total and these were excluded from the data analyses. In addition, naming latencies less than 250 ms or greater than 1200 ms were classified as errors and excluded from the latency analyses. A total of 44 data points (3.06%) were excluded in this fashion. Mean naming latencies of correct responses and mean error rates were calculated across participants and items separately. The mean naming latencies and error rates from the subjects' analyses are presented in Table 6.

In the analyses of naming latencies, the 56 ms frequency effect was significant both in the subjects' and the items' analyses, $t_s(23) = 9.31$, $p < .001$; $t_i(58) = 2.82$, $p < .01$. In the analyses of error rates, the 4.26% frequency effect was significant in the subjects' analysis, $t_s(23) = 2.84$, $p < .01$, although not in the items' analysis, $t_i(58) = 1.21$, $p > .10$.

Naming task with Katakana transcriptions

A trial was considered a mechanical error if the participant's vocal response failed to trigger the voice

Table 6
Mean lexical decision and naming latencies in milliseconds and error rates in percent in Experiment 4

Task: Stimulus type		Word frequency		RT difference
		Low	High	
Lexical decision tasks				
Kanji words	RT	587 (77.54)	548 (69.34)	+39
	ER	13.06 (7.22)	5.97 (5.73)	
Katakana transcriptions	RT	801 (91.01)	794 (100.55)	+7
	ER	17.22 (7.06)	13.89 (6.35)	
Naming tasks				
Kanji words	RT	705 (82.29)	649 (84.15)	+56
	ER	12.24 (8.09)	7.98 (6.15)	
Katakana transcriptions	RT	573 (109.19)	567 (103.18)	+6
	ER	4.45 (3.37)	4.05 (3.56)	

Note. RT and ER stand for mean reaction time and error rate, respectively. Standard deviation is in parenthesis. In the lexical decision task with Kanji words, mean lexical decision latency and error rate for Kanji nonwords were 683 ms ($SD = 114.56$) and 14.03% ($SD = 9.30$), respectively. In the lexical decision task with Katakana transcriptions, mean lexical decision latency and error rate for Katakana nonwords were 890 ms ($SD = 109.74$) and 8.19% ($SD = 6.65$), respectively.

key or if an extraneous sound triggered the voice key. There were 5 mechanical errors (0.35%) in total and these were excluded from the data analyses. In addition, naming latencies less than 250 ms or greater than 1200 ms were classified as errors and excluded from the latency analyses. A total of 7 data points (0.49%) were excluded in this fashion. Mean naming latencies of correct responses and mean error rates were calculated across participants and items separately. The mean naming latencies and error rates from the subjects' analyses are presented in Table 6.

In the analyses of naming latencies, the 6 ms frequency effect was not significant in either analysis, $t_s(23) = 1.67$; $t_i(58) = .39$, nor was the 0.40% frequency effect in the analyses of error rates, $t_s(23) = .45$; $t_i(58) = .24$.

Discussion

Significant frequency effects were observed in response latencies and error rates for the original Kanji words in both lexical decision and naming tasks, whereas for their Katakana transcriptions, significant frequency effects were not observed in the analyses of the latency data in either task (as in Experiments 2 and 3). As such, even with lower error rates, lexical decision latencies for the Katakana transcriptions were not sensitive to the word frequency of the original Kanji words. Similarly, even without nonword stimuli in the stimulus set, naming latencies for the Katakana transcriptions were not sensitive to the word frequency of the original Kanji words. Further, given the significant frequency effect for the original Kanji words, the lack of a frequency effect for the Katakana transcriptions cannot be attributed to any articulation onset differences between the high and low frequency conditions. Thus, these results are consistent with the conclusion that the results of the previous experiments were not due to the selected methodology.

One might also note that, in the lexical decision task, participants' responses were faster and more accurate for the original Kanji words than for their Katakana transcriptions. In contrast, in the naming task, responses were slower and less accurate for the original Kanji words than for their Katakana transcriptions. These results appear to reflect the fact that phonological coding is more difficult for Kanji words than for their Katakana transcriptions. As previously noted, each Katakana character corresponds to a single syllable (mora), whereas each Kanji character generally possesses multiple pronunciations. Due to the greater inconsistency between orthography and phonology for Kanji words than for their Katakana transcriptions, it would be expected that phonological coding would be more difficult for Kanji words than for their Katakana transcriptions.

General discussion

Masked repetition priming effects have been taken as empirical support for the conception of the lexicon offered by classical lexical models. In the present paper, we examined word frequency and masked repetition priming effects across different types of Japanese scripts using lexical decision and naming tasks as a means of examining the strength of this evidence. Our experimental results are summarized in Table 7.

First, cross-script masked repetition priming effects were observed in Japanese. That is, it was possible to obtain masked repetition priming effects when the orthographic characteristics of the prime and target were completely different. In addition, when word targets were presented in their normal scripts in our lexical decision tasks (Experiments 1 and 2), the masked repetition priming effects were observed only for word targets and these effects were additive with word frequency in the latency data (although interactive in the error data). Thus far, these results are consistent with those reported by Forster and Davis (1984) and, hence, they support the argument that abstract lexical units do exist and that masked repetition priming effects are due to the activation of these abstract lexical units.

When the results for word targets presented in an unfamiliar script are also considered, however, it becomes difficult to explain our results in terms of a lexical activation account. First of all, the sizes of masked repetition priming effects were modulated by the script familiarity of the target stimuli, although only in lexical decision tasks. Whereas masked repetition priming effects were smaller when word targets were presented in a familiar script than when they were presented in an unfamiliar script in lexical decision tasks (Experiments 1 and 2), the sizes of the masked repetition priming effects were virtually the same for the familiar and unfamiliar script targets in a naming task (Experiment 3). In addition, a frequency by script familiarity interaction was observed in both lexical decision and naming tasks. Whereas a significant frequency effect was observed when words were presented in a familiar script (in Experiments 1, 2, 3, and 4), the effect was diminished (in Experiment 1) or eliminated (in Experiments 2, 3, and 4) when these words were presented in an unfamiliar script in both tasks. Finally, we replicated the significant masked repetition priming effects for nonwords in a naming task, as reported by Masson and Isaak (1999), as well as the finding that the sizes of the masked repetition priming effects were similar for words and nonwords.

According to the lexical activation account, any significant cross-script masked repetition priming effects would be due to the automatic activation of the abstract lexical units. This account has the following difficulties explaining the results of our experiments. Assuming that masked repetition priming effects are due solely to lexical

Table 7
Masked repetition priming, word frequency, and lexicality effect sizes observed in Experiments 1, 2, 3, and 4

Experiment: Target type	Repetition effect	Frequency effect	Lexicality effect
Experiment 1: (*Lexical decision task*)			
Familiar Kanji-word targets	+17*	+114*	
Kanji-nonword targets	−3		
Unfamiliar Katakana-transcription targets	+125*	+52*	
Katakana-nonword Targets	+8		
Experiment 2: (*Lexical decision task*)			
Familiar Katakana-word targets	+17*	+55*	
Katakana-nonword targets	+20		
Unfamiliar Katakana-transcription targets	+47*	−4	
Katakana-nonword targets	+8		
Experiment 3: (*Naming Task*)			
Familiar Katakana-word targets	+14*	+16*	+86*
Katakana-nonword targets	+20*		
Unfamiliar Katakana-transcription targets	+20*	+2	+35*
Katakana-nonword targets	+16*		
Experiment 4: (*Lexical decision task*)			
Familiar Kanji-word targets		+39*	
Unfamiliar Katakana-transcription targets		+7	
Experiment 4: (*Naming task*)			
Familiar Kanji-word targets		+56*	
Unfamiliar Katakana-transcription targets		+6	

* $p < .05$.

activation, there would be no reason to expect that the effect sizes would be modulated by the script familiarity of the targets. In addition, if lexical units are assumed to be frequency sensitive, this account predicts that a masked repetition priming effect should always be accompanied by a frequency effect. Although masked repetition priming effects were significant for the unfamiliar transcription targets, we failed to observe a frequency effect for these targets in both lexical decision and naming tasks.

These problems appear to be solved, however, if we assume that what is frequency sensitive is not the lexical units themselves but the linkage between sublexical and lexical units and that the lexical-selection process shows a greater amount of facilitation (due to the pre-activation of the lexical units) when this process is driven by phonological units. Nonetheless, even this amended lexical activation account has problems. Particularly, it fails to explain the existence of masked repetition priming effects for nonwords. In the remainder of the General discussion we will consider how well alternatives to this account can explain the present data and, at the end, will discuss how this account might be amended in order to explain masked repetition priming of nonwords.

Masked repetition priming as a phonological activation phenomenon

Given the difficulty in explaining these results in terms of the lexical activation account, the first question is whether it is possible to explain our results in terms of the phonological activation account. Assuming that masked repetition priming effects are due solely to phonological activation, the Repetition by Script Familiarity interaction in lexical decision and the lack of this interaction in naming would be expected. In addition, this account is also consistent with the similar size masked repetition priming effects for word and nonword targets in our naming task. Further, because our unfamiliar transcription targets are written in the shallow Katakana script, phonological coding for these transcriptions would, in general, be done nonlexically, whereas lexical phonological coding would typically be involved for the familiar Katakana word targets. As a result, a much larger frequency effect should be observed for the Katakana word targets than for the Katakana transcription targets in the naming task, as was observed.

This assumption that both transcriptions and nonwords are named nonlexically, however, causes the basic phonological activation account to run into a problem. That is, it causes this account to fail to explain the naming advantage for the transcriptions over the nonwords. As noted, this account also fails to explain the Frequency by Script Familiarity interaction in our lexical decision tasks if the assumption that frequency sensitivity is in the lexical units themselves is maintained. If, however, this account is modified by assuming that what is frequency sensitive is the links between sublexical and lexical units, these problems can be solved. That is, the account can then explain the lack of a frequency effect for the unfamiliar transcriptions in the lexical decision tasks and, in line with McCann and Besner's (1987) arguments, the account can also explain the latency advantage for the unfamiliar transcription targets over the nonword targets in our naming task. That is, as suggested by McCann and Besner (see also Besner, 1999; Besner & Hildebrandt, 1987), if it is assumed that there is an interaction between phonological units and lexical units, this interaction could facilitate phonological coding (or articulatory code generation) for the transcriptions but not for the nonwords. As such, in contrast to the lexical activation account, the amended phonological activation account appears to be consistent with virtually all of our results.

PDP accounts

Given that our results appear to be explained better in terms of phonological activation than in terms of the activation of lexical units, a reasonable question would be whether it is possible to account for our results in terms of a theory that doesn't contain lexical units at all. In fact, Masson and colleagues (Masson, 1999; Masson & Isaak, 1999) and Van Orden et al. (1990) suggested phonological activation accounts of masked repetition priming effects based on PDP-type models, models that do not assume the existence of lexical units. How successful would these types of models be here?

First, assuming that orthographic units are script dependent for Japanese words, a model of this sort would explain the cross-script masked repetition priming effects as being due to the activation of phonological units that are shared by orthographically different prime and target stimuli. This assumption would be quite consistent with the similar size repetition priming effects for words and nonwords in the naming task of Experiment 3.

In addition, according to this type of model, frequency effects are task-dependent effects. Seidenberg and McClelland (1989), for example, suggested that the word frequency effect in a lexical decision task is due to a task-specific decision-making process, which is typically driven by the orthographic familiarity of stimuli. In a naming task, on the other hand, the frequency effect is assumed to be due to the process of phonological coding, a process that is assumed to be required to produce pronunciation responses. Based on these assumptions, this type of model would also be able to account for the Frequency by Script Familiarity interaction in both naming and lexical decision tasks.

That is, it is generally assumed in PDP models that the speed of phonological coding is modulated by the frequency and consistency of the experienced orthographic-to-phonological mappings. When Japanese words are presented in their normal script, the phonological coding would be driven by familiar orthographic codes and, hence, the speed of phonological coding would be modulated by frequency. When words are transcribed into an unfamiliar script, however, the phonological coding process would have to be driven by novel orthographic codes regardless of word frequency. Thus, the phonological coding process for these unfamiliar transcriptions would become essentially the same as that of the nonlexical route in the dual-route model (e.g., Coltheart, 1978; Coltheart et al., 1993), a process which is unaffected by word frequency. As such, a PDP-type model could explain the Frequency by Script Familiarity interaction (in particular, the lack of frequency effects for the unfamiliar script targets) in the naming task of Experiment 3.

With respect to the lexical decision task, the model would have to assume that a central component of this task is the decision-making process, which would be driven by stimulus familiarity (e.g., Masson, 1999; Plaut, 1997; Seidenberg & McClelland, 1989). As long as orthographic familiarity provides enough of a clue to discriminate words from nonwords, this decision-making process would play a major role and would be responsible for the frequency effect in lexical decision tasks. This process presumably played the major role in making lexical decisions for familiar word targets because those words were familiar orthographic patterns.

By transcribing these words into an unfamiliar script, however, the orthographic familiarity would be severely reduced and, hence, orthographic familiarity differences between words and nonwords would be minimized for both high and low frequency words. As a result, it would become difficult to distinguish words from nonwords on the basis of orthographic familiarity. In such circumstances, phonological information would tend to be recruited in making decisions (Hino & Lupker, 1996; Seidenberg & McClelland, 1989; Waters & Seidenberg, 1985). More specifically, as previously noted by a number of researchers (e.g., Lesch & Pollatsek, 1993; Lukatela et al., 1998; Lukatela & Turvey, 1994; Perfetti et al., 1988; Perfetti & Zhang, 1991, 1995; Tan et al., 1995; Van Orden, 1987; Van Orden et al., 1988; Wydell et al., 1993) phonological information is automatically available quite early in processing. When words were transcribed into an unfamiliar script, because the orthographic familiarity of these transcriptions is minimal (because they are normally written only in a familiar script), participants recruit this readily available phonological information in making their decisions.

Further, it would also be possible to argue that evaluating the phonological familiarity of these stimuli would essentially be a process of judging how easy it was to apply character-to-sound mappings in order to generate the character string's phonological code. Such a process may be sensitive to the frequency of the individual character-to-sound mappings; however, it would be virtually insensitive to word frequency for our transcriptions. Thus, this type of model also suggests that the frequency effect should be severely diminished for unfamiliar transcriptions in our lexical decision tasks in Experiments 1 and 2.

Note that our assumption that the decision-making process for our transcriptions was based on the familiarity of the character-to-sound translation process rather than the familiarity of the resulting phonological code is a key assumption. If this process were based on the familiarity of the resulting phonological code, we very likely would have observed a frequency effect based on the differences in spoken frequency of our high and low frequency transcriptions. That is, because spoken frequency is correlated with printed frequency, high printed-frequency words undoubtedly have higher spoken frequency than low printed-frequency words. If so, the phonological codes for the high printed-frequency words should have been more familiar than the phonological codes for the low printed-frequency words even when these words were transcribed into an unfamiliar script. Thus, if the familiarity of the phonological codes were being used in the decision-making process, one would have expected to have obtained a frequency effect.

In fact, this alternative argument, that the familiarity of phonological codes is a key element in phonologically based lexical decisions, has been proposed by McCann et al. (1998). As previously noted, consistent with our lack of a frequency effect with the unfamiliar transcriptions in naming tasks, McCann and Besner (1987) failed to observe a base-word frequency effect for pseudohomophones in their naming task (but see Marmurek & Kwantes, 1996). On the other hand, in contrast to our lexical decision results for our unfamiliar transcriptions, McCann et al. (1988) did observe a significant base-word frequency effect for pseudohomophones in a phonological lexical decision task. In phonological lexical decision tasks, participants must respond positively if the letter string sounds like a word. That is, they must respond positively to both words and pseudohomophones. Thus, phonological lexical decision tasks would appear to be the English equivalent of our lexical decision tasks with unfamiliar transcriptions as word targets because in both tasks, participants are forced to rely on phonological information to make lexical-type decisions. Nonetheless, although we consistently failed to observe a frequency effect in the latency data for our unfamiliar transcriptions, McCann et al. did observe a base-word frequency effect for pseudohomophones in their phonological lexical decision task. As such, McCann et al. argued that spoken frequency should matter when participants were asked to make phonologically based decisions.

One possible explanation for the difference between our results and those of McCann et al. (1988) would be that Katakana transcriptions and English pseudohomophones are simply processed differently. For example, pseudohomophones are inevitably orthographically similar to their base words (e.g., BRANE—BRAIN) while Katakana transcriptions look nothing like their Kanji-written words. Thus, the orthographic familiarity of the base word may play a larger role when analyzing pseudohomophones than the orthographic familiarity of the Kanji form plays when analyzing Katakana transcriptions. If so, the effect that McCann et al. observed would have actually had more to do with orthographic familiarity than with phonological familiarity.

Other effects that would be consistent with the PDP-based phonological activation account are the significant Repetition by Script Familiarity interaction in lexical decision, and the lack of this interaction in naming. As we noted above, when word targets were familiar word stimuli in our lexical decision tasks, the decision-making process would have been predominantly based on orthographic information because the orthographic familiarity of stimuli would provide enough of a clue to discriminate words from nonwords. When lexical decision targets were unfamiliar transcriptions, on the other hand, participants would have relied more on phonological information in making their decisions. The result of this switch from orthographically based processing to phonologically based processing produces the Repetition by Script Familiarity interaction (i.e., the fact that priming effects are larger with the transcriptions). That is, according to this type of model, cross-script masked repetition priming effects are produced by the phonological activation created by masked prime stimuli. Therefore, phonological activation should have a larger effect when lexical decisions are based on phonological information, resulting in the larger repetition priming effect for the unfamiliar transcription targets than for the familiar word targets.

In addition, this type of model also seems capable of explaining the lack of a Repetition by Script Familiarity interaction in the naming task. That is, assuming that masked primes produce phonological activation, this activation would be more effective when phonological information plays a central role in target processing. Because a naming task always requires pronunciation responses and, hence, phonological coding for all stimuli (e.g., Hino & Lupker, 1996; Seidenberg & McClelland, 1989; Waters & Seidenberg, 1985), if the sizes of repetition priming effects depend on the degree to which participants use phonological information for target processing, the interaction between Repetition and Script Familiarity should be much smaller in a naming task than in a lexical decision task, as was observed.

Finally, the significant masked repetition priming of nonwords in naming but not in lexical decision could also be accounted for if it is assumed that the facilitation of target processing produced by a masked repetition prime also produces a "word" bias. When the target is a nonword, this word bias then slows the decision-making process (e.g., Bodner & Masson, 1997).

As such, a PDP-type model which postulates that repetition priming is due to phonological activation appears to be consistent with most of our findings. This type of model does run into a problem, however. What is problematic for this model is the lexicality effect for the unfamiliar script targets in our naming task (Experiment 3). That is, if phonological coding is driven by novel orthographic codes for the unfamiliar script targets, there would be no reason to expect naming latencies for word targets to be faster than those for nonword targets (e.g., Besner, 1999; Besner, Twilley, McCann, & Seergobin, 1990; Seidenberg & McClelland, 1990; Seidenberg, Petersen, MacDonald, & Plaut, 1996).

One way in which a PDP-type model could account for this lexicality effect would be to assume that the effect is due to an interaction between phonology and semantics (e.g., Plaut et al., 1996; Seidenberg & McClelland, 1990). Support for this assumption is found in Hino, Lupker, and Besner's (1998) report of a significant ambiguity (number of meanings) effect in the naming of not only Katakana words but also their Hiragana transcriptions. These results indicate that semantic information is activated when activating phonological codes even when those phonological codes are activated by unfamiliar orthographic units. The results also suggest that this activation then feeds back to those phonological units to aid their activation, producing an ambiguity effect even for the transcriptions. Thus, in terms of the present results, the proposal would be that what appears to be a lexicality effect in the naming of the unfamiliar transcriptions may actually be an effect of semantic feedback to phonological units.

Recent results reported by Gollan, Forster, and Frost (1997) examining masked translation priming for Hebrew–English bilinguals would appear to be consistent with this idea. In their lexical decision experiments, masked translation priming effects were observed when primes were in their participants' first language (L1) and targets were in their second language (L2), although priming effects were small or nonexistent when L2 primes were followed by L1 targets. In addition, the effect sizes were larger when their primes and targets had similar orthographic and phonological properties (i.e., when they were cognates) than when they did not (i.e., when they were noncognates), especially when the participants were less fluent in their second language.

While most of Gollan et al.'s (1997) results are quite consistent with a phonological-activation account framed within a PDP architecture, the one result that is not is their demonstration of a masked translation priming effect for noncognates. However, if we make the assumption that word recognition is affected by an interaction between phonology and semantics, as Hino et al. (1998) have suggested, this account would fare much better. That is, when a masked prime is presented, it automatically activates its phonological code as well as its semantic code. The activated semantic code would then produce feedback activation to corresponding phonological codes (i.e., phonological codes for both languages). As a result, a translation priming effect would be expected to arise as a result of this phonological activation and, in addition, the effect should be larger for cognates (which share phonology) than for noncognates.

Nonetheless, Gollan et al. (1997) have argued that it would be difficult to account for their results in terms of semantics because previous studies using the masked priming paradigm obtained very small or nonsignificant priming effects for semantically related pairs (e.g., de Groot & Nas, 1991; Frost, Forster, & Deutsch, 1997). Note, however, that the role of semantics in semantic priming experiments and the role of semantics in cross-language repetition priming (according to this feedback proposal) are somewhat different. According to this proposal, the role of semantics in cross-language repetition priming would be to reinforce the phonological activation of the presented letter string. This feedback would be taking advantage of well-learned phonology-to-semantic-to-phonology links because it would be directed only to the appropriate phonological code(s). In semantic priming experiments, however, activated semantic information must activate either orthographic or phonological information for a nonpresented letter string (and for a nonpresented semantic concept). The activation that would be expected to feed back from semantics to codes for related concepts would be substantially smaller than the activation that would be expected to feed back from semantics to codes for the presented concept. Therefore, the fact that masked semantic priming effects tend to be quite small would not appear to be problematic for an account based on feedback within a PDP system.

Masked repetition priming as a lexical activation phenomenon

As noted, the lack of a frequency effect for the transcriptions is a problem for the basic lexical activation account. Although this problem can be solved if one assumes that frequency effects are due to the nature of the links between orthographic and lexical units rather than to the nature of the lexical units themselves, this amended lexical activation account still has the problem of explaining the masked repetition priming effect for nonword targets in the naming task of Experiment 3. This effect cannot be explained in terms of lexical activation because nonwords have no lexical representations. Thus, it would be necessary to propose a secondary locus. The two obvious possibilities would be the process of generating a phonological code or the process of generating an articulatory code.

An account based on the phonological code generation process would parallel the phonological activation account discussed above. That is, it would be based on the idea that the phonological codes for nonwords were assembled through the nonlexical route. Any phonological codes that the prime had pre-activated would be appropriate codes for the repeated target, making the generation process easier and producing a repetition priming effect. A similar account could be proposed based on the process of generating an articulatory code. That is, the prime would pre-activate some articulatory codes appropriate for the repeated target, facilitating the articulation process (see also Forster, 1998).

In either situation, however, two further issues would need to be addressed. First, what would these accounts predict about the facilitation of words in a naming task? Second, can the account then also offer an explanation for the lexicality effect?

Consider first how these questions would be answered for an account which claims that the nonword priming effect arises during the phonological code generation process. One can certainly hypothesize that, as described in the dual-route model (Coltheart, 1978; Coltheart et al., 1993), word naming involves both a lexical and nonlexical route. The priming that target stimuli exhibit would be a function of the way in which they were named. In the case of the Katakana words, most of the time they would be named via the lexical route and, hence, most of the facilitation would come from lexical activation. In contrast, in the case of the nonwords, most of the facilitation would come from the phonological code generation process (i.e., through the pre-activation of phonological codes). With respect to the transcriptions, lexical selection can only be accomplished once a nonlexical phonological code has been generated. Thus, transcriptions would presumably typically be named through the use of that code (i.e., via the nonlexical route) rather than through a code retrieved following lexical selection. Hence, they also would be facilitated through the pre-activation of phonological codes. The important point, however, is that there would be no reason to assume that one form of facilitation was more potent than the other. Hence, it would be quite possible that equivalent priming effects would be found for Katakana words, Katakana transcriptions, and Katakana nonwords.

There is still, however, the problem of explaining the lexicality effect. That is, if transcriptions are named in essentially the same way that nonwords are, then there would be no reason for the transcriptions to show a latency advantage. To explain this result, one would need to add the further assumption that the transcriptions benefited from lexical/semantic feedback or that they benefited at the articulatory level due to the fact that transcriptions have a familiar articulatory code.

Suppose, instead, that the locus of the facilitation for the nonwords was assumed to be the articulatory, rather than the phonological, level. One immediate problem of adding this assumption is that the expectation would then be that words should show larger priming effects than nonwords. That is, words would benefit not only from priming at the articulatory level but also from priming at the lexical level. Unfortunately, the results of Experiment 3 showed that, if anything, nonwords actually produced slightly larger repetition priming effects than Katakana words.[7]

To solve this problem, one could assume that the amount of priming one can get from the articulatory process is a function of the familiarity of the articulatory code. That is, producing well-learned articulatory codes may be sufficiently rapid that little priming would be possible. Thus, words would benefit to a much smaller degree at the articulatory level than nonwords would. As a result, the overall level of priming for words, which benefit from priming at the lexical level, and nonwords, which do not, would be fairly equivalent. Note that this hypothesis would also explain the lexicality effect. That is, the reason that transcriptions are named faster than nonwords would be because the transcriptions have a well-learned and, hence, easily retrieved, articulatory code.

Is it possible to preserve an orthographic account?

Throughout this paper, we have assumed that, because there are no obvious relationships between the characters in Japanese scripts, any repetition priming effects that we observed could not be orthographic effects. Such an assumption could be challenged if one wished to argue that the word recognition system is strongly interactive and interconnected. For example, one could propose that the orthographic codes for Kanji representations and Katakana representations are indirectly linked through their shared phonological codes. As a result, when a Kanji prime is viewed, it would activate its phonological representation which would then activate the orthographic representations consistent with that phonological code in the Katakana system. If a repeated Katakana target followed, its processing would be facilitated due to this pre-activation of its orthographic representation. Thus, if one does make these assumptions, it might still be possible to explain cross-script priming as an orthographic phenomenon.[8]

[7] One may argue that the similar size repetition priming effects for word and nonword targets in Experiment 3 may be a product of the brief, 32 ms prime duration. That is, the maximal priming effect would be fairly low at this brief prime duration and, as a consequence, it would be quite difficult to detect any effect size difference between word and nonword targets. Note, however, that Masson and Isaak (1999) observed similar size repetition priming effects for word and nonword targets even when the prime durations were longer (50 and 60 ms in their two experiments). Thus, it seems unlikely that the lack of the priming effect size difference between word and nonword targets in Experiment 3 was due simply to our brief prime duration.

[8] We thank Mike Masson for suggesting this alternative account.

If these notions were incorporated into a PDP-type system, such as that described above, it would account for most of the present results. Where it might run into trouble would be in explaining why the priming effect for the transcriptions was so much smaller in naming than in lexical decision. If the effect were purely due to pre-activation of orthographic codes, it would essentially be an input effect. Thus, the most obvious prediction would be that the effect would be the same size in any task that required orthographic coding. To circumvent this problem, one would have to further assume that the larger effects in lexical decision were due to more extensive use of orthographic codes in that task than in naming. In particular, one would need to argue that the process of making a lexical decision with words in an unfamiliar script was still orthographically based in spite of the fact that the orthographic patterns were all novel. Thus, the pre-activation of orthographic codes would be much more useful to processing in lexical decision than in naming and, hence, could produce a larger priming effect. Whether these assumptions (both processing and structural) actually are realistic is a question for future research.

Conclusion

As noted above, the existence of masked repetition priming effects with visually different primes and targets in English has been taken as strong evidence for the conception of the lexicon offered by classical lexical models and for a lexical activation account of these priming effects. As the present discussion indicates, however, a framework of this sort actually has considerable difficulty explaining masked repetition priming effects unless a number of additional, ad hoc assumptions are added. Further, as this discussion also indicates, the present data can be equally well explained in terms of a phonological activation account regardless of whether that account is framed in terms of a lexical model or in terms of a PDP-type model.

When faced with such a situation, the superior model is generally taken to be the one which is most parsimonious. Unfortunately, the question of parsimony is a rather subjective one. Although we believe the phonological activation account is more parsimonious when framed in terms of a PDP-type model, others may disagree. The more important point, however, is simply that an unadorned lexical model does not provide a good explanation of the masked repetition priming effects observed in the present experiments. Thus, the existence of masked repetition priming effects across visually different primes and targets actually provides very little evidence for that type of model. Rather, support for the model and its core assumptions, for example, the existence of abstract lexical units, one of the key principles that distinguishes classical lexical models from PDP-type models, will need to come from other word-recognition phenomena.

Acknowledgments

Experiment 1 was conducted as the part of Taeko Ogawa's graduation thesis study at Department of Psychology, Chukyo University. The authors thank Tetsuro Tajima, Akiko Uchida, and Yoko Atoda for their assistance in the data collection. The authors also thank Ken Forster, Fernanda Ferreira, Derek Besner, Mike Masson, and two anonymous reviewers for their comments on earlier versions of the manuscript.

Appendix A. Kanji words and their Katakana transcriptors used in Experiment 1, along with their English translations

Kanji word	Katakana transcription	English translation
Low frequency		
分校	ブンコウ	branch school
鉱山	コウザン	mine for natural resources
陣営	ジンエイ	camp
端的	タンテキ	frank, direct
議決	ギケツ	decision
側面	ソクメン	side, aspect
金具	カナグ	metal fittings
解剖	カイボウ	dissection
本位	ホンイ	standard, center, self
発熱	ハツネツ	attack of fever
円滑	エンカツ	smooth
即売	ソクバイ	spot sale
苦戦	クセン	hard fight, desperate battle
持続	ジゾク	continuance, continuation
初恋	ハツコイ	one's first love
肉親	ニクシン	blood relationship
竹馬	タケウマ	stilts
原油	ゲンユ	crude oil
High frequency		
報道	ホウドウ	news, information
格安	カクヤス	bargain
芸能	ゲイノウ	public entertainments
空港	クウコウ	airport
警察	ケイサツ	police
郵便	ユウビン	mail
質問	シツモン	question
部分	ブブン	part, portion
予想	ヨソウ	expectation, anticipation
外国	ガイコク	foreign country
番組	バングミ	program
道路	ドウロ	road, street
会話	カイワ	conversation
店員	テンイン	salesclerk, shop assistant
事件	ジケン	event, incident, affair
計画	ケイカク	plan, project, scheme
学歴	ガクレキ	academic career
予算	ヨサン	budget

Appendix B. Katakana word and Katakana transcription (of Kanji word) repeated pairs used in Experiments 2, 3 and 4, along with their English translations

Hiragana prime	Katakana target	English translation
Katakana/High frequency		
ぎたあ	ギター	guitar
はうす	ハウス	house
ひっと	ヒット	hit
あらぶ	アラブ	Arab
しねま	シネマ	the cinema
てえま	テーマ	theme
かなだ	カナダ	Canada
はがき	ハガキ	postcard
ばいと	バイト	part-time job
べすと	ベスト	best, vest
かめら	カメラ	camera
ごるふ	ゴルフ	golf
たいぷ	タイプ	type
いんど	インド	India
こおす	コース	course
とよた	トヨタ	Toyota
すたあ	スター	star
あじあ	アジア	Asia
あるぷす	アルプス	the Alps
ばらんす	バランス	balance
しいずん	シーズン	season
とらっく	トラック	truck, track
すぴいど	スピード	speed
ばあてん	バーテン	bartender
にっぽん	ニッポン	Japan
だいやる	ダイヤル	dial
あぱあと	アパート	apartment
あふりか	アフリカ	Africa
ふらんす	フランス	France
あめりか	アメリカ	America
Katakana/Low frequency		
はしご	ハシゴ	ladder
あいぬ	アイヌ	Ainu
せりふ	セリフ	words
しいと	シート	sheet, seat
にっと	ニット	knitware
とらい	トライ	try
てんと	テント	tent
からす	カラス	crow
すかい	スカイ	sky
ぎにあ	ギニア	Guinea
あぽろ	アポロ	Apollo
いわし	イワシ	sardine
ごりら	ゴリラ	gorilla
はさみ	ハサミ	scissors
たいる	タイル	tile
こらむ	コラム	column
かっと	カット	cut
でるた	デルタ	delta
ふんどし	フンドシ	loincloth
せくしい	セクシー	sexy
だあびい	ダービー	the Derby
あまぞん	アマゾン	Amazon
こんどる	コンドル	condor
あんてな	アンテナ	antenna

Appendix B. (*continued*)

Hiragana prime	Katakana target	English translation
もろっこ	モロッコ	Morocco
あべっく	アベック	couple
ほるもん	ホルモン	hormone
すけえる	スケール	scale
せいろん	セイロン	Ceylon
なんばあ	ナンバー	number

Hiragana prime	Katakana target	Kanji word	English translation
Kanji/High frequency			
ごうい	ゴウイ	合意	agreement
ぎのう	ギノウ	技能	skill
はいし	ハイシ	廃止	abolition, abandon
すうじ	スウジ	数字	number, digit
はけん	ハケン	派遣	dispatch
ひよう	ヒヨウ	費用	expenses
ていし	テイシ	停止	stop, suspend
かいし	カイシ	開始	begin, start
ちしき	チシキ	知識	knowledge
とうぎ	トウギ	討議	discussion
たいほ	タイホ	逮捕	arrest
しそう	シソウ	思想	thought, idea
ばんち	バンチ	番地	address
あいて	アイテ	相手	companion
いらい	イライ	以来	since, from
せいび	セイビ	整備	fix, repair
かくち	カクチ	各地	various places
かいわ	カイワ	会話	conversation
べっそう	ベッソウ	別荘	cottage
だんせい	ダンセイ	男性	man, male
ばいてん	バイテン	売店	stand, store
あかさか	アカサカ	赤坂	Akasaka, a name of a town in Tokyo
どうめい	ドウメイ	同盟	alliance
もくぞう	モクゾウ	木造	wooden, made of wood
すいさん	スイサン	水産	fisheries
すいしん	スイシン	推進	propel
ぼうえい	ボウエイ	防衛	defense
ていこく	テイコク	帝国	empire
あんてい	アンテイ	安定	stability
せいさん	セイサン	生産	production
Kanji/Low frequency			
いへん	イヘン	異変	accident, disaster
とこう	トコウ	渡航	going abroad
かなぐ	カナグ	金具	metal fittings
あしば	アシバ	足場	scaffold
ばくろ	バクロ	暴露	expose, reveal
はんが	ハンガ	版画	print, woodblock
はおり	ハオリ	羽織	Haori, a Japanese clothing
ごがく	ゴガク	語学	(learning) languages
ぎぞう	ギゾウ	偽造	camouflage
しへい	シヘイ	紙幣	bill, paper money
あいず	アイズ	合図	signal
ひれい	ヒレイ	比例	proportional relationship
てんち	テンチ	天地	heaven and earth
せなか	セナカ	背中	back
こりつ	コリツ	孤立	alone, isolated
にもつ	ニモツ	荷物	load, baggage
すはだ	スハダ	素肌	bare skin
ふうど	フウド	風土	climate, environment
とうたつ	トウタツ	到達	reach, arrive

Appendix B. (*continued*)

Hiragana prime	Katakana target	Kanji word	English translation
えんかつ	エンカツ	円滑	smooth
でんげき	デンゲキ	電撃	electric shock, suddenness
しんこん	シンコン	新婚	newly married couple
あしくび	アシクビ	足首	ankle
あいこく	アイコク	愛国	patriotic
たんすい	タンスイ	淡水	fresh water
もくろく	モクロク	目録	list, catalogue
すいへい	スイヘイ	水兵	sailor
だんやく	ダンヤク	弾薬	ammunition
すいこう	スイコウ	遂行	execution
すいそく	スイソク	推測	guess, conjecture

References

Balota, D. A. (1990). The role of meaning in word recognition. In D. A. Balota, G. B. Flores d'Arcaise, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 9–32). Hillsdale, HJ: Lawrence Erlbaum.

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 340–357.

Balota, D. A., & Chumbley, J. I. (1985). The locus of word-frequency effects in the pronunciation task: Lexical access and/or production? *Journal of Memory and Language, 24*, 89–106.

Balota, D. A., Pilotti, M., & Cortese, M. J. (2001). Subjective frequency estimates for 2,938 monosyllabic words. *Memory & Cognition, 17*, 644–652.

Baluch, B., & Besner, D. (1991). Visual word recognition: Evidence for strategic control of lexical and nonlexical routines in oral reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 644–652.

Becker, C. A. (1976). Allocation of attention during visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 556–566.

Besner, D. (1983). Basic decoding components in reading: Two dissociable feature extraction processes. *Canadian Journal of Psychology, 37*, 429–438.

Besner, D. (1999). Basic processes in reading: Multiple routines in localist and connectionist models. In P. A. McMullen & R. M. Klein (Eds.), *Converging methods for understanding reading and dyslexia* (pp. 413–458). Cambridge, MA: MIT Press.

Besner, D., & Hildebrandt, N. (1987). Orthographic and phonological codes in the oral reading of Japanese kana. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 335–343.

Besner, D., & McCann, R. S. (1987). Word frequency and pattern distortion in visual word identification and production: An examination of four classes of models. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 201–243). Hillsdale, NJ: Erlbaum.

Besner, D., & Smith, M. C. (1992). Models of visual word recognition: When obscuring the stimulus yields a clearer view. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 468–482.

Besner, D., Twilley, L., McCann, R. S., & Seergobin, K. (1990). On the association between connnectionism and data: Are a few words necessary? *Psychological Review, 97*, 432–446.

Bodner, G. E., & Masson, M. E. J. (1997). Masked repetition priming of words and nonwords: Evidence for a nonlexical basis for priming. *Journal of Memory and Language, 37*, 268–293.

Borowsky, R., & Masson, M. E. J. (1999). Frequency effects and lexical access: On the interpretation of null pseudohomophone base-word frequency effects. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 270–275.

Cohen, J. (1976). Random means random. *Journal of Verbal Learning and Verbal Behavior, 15*, 261–262.

Clark, H. H. (1973). The language-as fixed-effect fallacy: A critique of language statistics in psychological research. *Journal of Verbal Learning and Verbal Behavior, 12*, 335–359.

Coltheart, M. (1978). Lexical access in simple reading tasks. In G. Underwood (Ed.), *Strategies of information processing* (pp. 151–216). London: Academic Press.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological Review, 100*, 589–608.

de Groot, A. M. B., & Nas, G. L. J. (1991). Lexical representation of cognates and noncognates in compound bilinguals. *Journal of Memory and Language, 30*, 90–123.

Evett, L. J., & Humphreys, G. W. (1981). The use of abstract graphemic information in lexical access. *The Quarterly Journal of Experimental Psychology A, 33*, 325–350.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. Walker (Eds.), *New approaches to language mechanisms* (pp. 257–287). Amsterdam: North-Holland.

Forster, K. I. (1998). The pros and cons of masked priming. *Journal of Psycholinguistic Research, 27*, 203–233.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 680–698.

Forster, K. I., & Davis, C. (1991). The density constraint on form-priming in the naming task: Interference effects from a masked prime. *Journal of Memory and Language, 30*, 1–25.

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

Frost, R., Forster, K. I., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 829–856.

Gernsbacher, M. A. (1984). Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. *Journal of Experimental Psychology: General, 113*, 256–281.

Gollan, T. H., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: Masked priming with cognates and noncognates in Hebrew–English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 1122–1139.

Hino, Y., & Lupker, S. J. (1996). Effects of polysemy in lexical decision and naming: An alternative to lexical access accounts. *Journal of Experimental Psychology: Human Perception and Performance, 22*, 1331–1356.

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

Hino, Y., & Lupker, S. J. (2000). The effects of word frequency and spelling-to-sound regularity in naming with and without preceding lexical decision. *Journal of Experimental Psychology: Human Perception and Performance, 26*, 166–183.

Hino, Y., Lupker, S. J., & Besner, D. (1998). *Polysemy effects in the naming of Japanese Katakana words and their Hiragana transcriptions*. Paper presented at the 39th Annual Meeting of the Psychonomic Society, Dallas, TX, USA.

Hudson, P. T. W., & Bergman, M. W. (1985). Lexical knowledge in word recognition: Word length in naming and lexical decision tasks. *Journal of Memory and Language, 24*, 46–58.

Keppel, G. (1976). Words as random variables. *Journal of Verbal Learning and Verbal Behavior, 15*, 263–265.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 285–294.

Lukatela, G., Frost, S. J., & Turvey, M. T. (1998). Phonological priming by masked nonword primes in the lexical decision task. *Journal of Memory and Language, 39*, 666–683.

Lukatela, G., Savic, M., Urosevic, Z., & Turvey, M. T. (1997). Phonological ambiguity impairs identity priming in naming and lexical decision. *Journal of Memory and Language, 36*, 360–381.

Lukatela, G., & Turvey, M. T. (1990). Phonemic similarity effects and prelexical phonology. *Memory & Cognition, 18*, 128–152.

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: 2. Evidence from phonological priming by homophones and pseudohomophones. *Journal of Experimental Psychology: General, 123*, 331–353.

Masson, M. E. J. (1999). Interactive processes in word identification: Modeling context effects in a distributed memory system. In P. A. McMullen & R. M. Klein (Eds.), *Converging methods for understanding reading and dyslexia* (pp. 373–411). Cambridge, MA: MIT Press.

Masson, M. E. J., & Isaak, M. I. (1999). Masked priming of words and nonwords in a naming task: Further evidence for a nonlexical basis for priming. *Memory & Cognition, 27*, 399–412.

McCann, R. S., & Besner, D. (1987). Reading pseudohomophones: Implications for models of pronunciation assembly and the locus of word-frequency effects in naming. *Journal of Experimental Psychology: Human Perception and Performance, 13*, 14–24.

McCann, R. S., Besner, D., & Davelaar, E. (1988). Word recognition and identification: Do word-frequency effects reflect lexical access? *Journal of Experimental Psychology: Human Perception and Performance, 14*, 693–706.

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

Morton, J. (1969). Interaction of information in word recognition. *Psychological Review, 76*, 165–178.

Marmurek, H. H. C., & Kwantes, P. J. (1996). Reading words and wirds: Phonology and lexical access. *The Quarterly Journal of Experimental Psychology A, 49*(3), 696–714.

National Language Research Institute (1963). *Gendai-zasshi 90 shu no yougo youji: Dai 2 bunsatsu, Kanji-hyou* [Vocabulary and Chinese characters in ninety magazines of today (Volume II), Chinese characters frequency tables]. Tokyo: Shuei Shuppan.

National Language Research Institute (1970). *Denshikeisanki niyoru shinbun no goi-chosa* [Studies on the vocabulary of modern newspapers (Volume 1), General descriptions and vocabulary frequency tables]. Tokyo: Shuei Shuppan.

National Language Research Institute (1993). *Bunrui Goi Hyou* (*Floppy Disk Version*) [Thesaurus (Floppy disk version)]. Tokyo: Shuei Shuppan.

Paap, K. R., McDonald, J. E., Schvaneveldt, R. W., & Noel, R. W. (1987). Frequency and pronounceability in visually presented naming and lexical decision tasks. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 221–243). Hillsdale, NJ: Erlbaum.

Paap, K. R., Newsome, S. L., McDonald, J. E., & Schvaneveldt, R. W. (1982). An activation-verification model for letter and word recognition: The word-superiority effect. *Psychological Review, 89*, 573–594.

Paap, K. R., Newsome, S. L., & Noel, R. W. (1984). Word shape's in poor shape for the race to the lexicon. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 413–428.

Perfetti, C. A., Bell, L. C., & Delaney, S. M. (1988). Automatic (prelexical) phonetic activation in silent word reading: Evidence from Backward masking. *Journal of Memory and Language, 27*, 59–70.

Perfetti, C. A., & Zhang, S. (1991). Phonological processes in reading Chinese characters. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 633–643.

Perfetti, C. A., & Zhang, S. (1995). Very early phonological activation in Chinese reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 24–33.

Plaut, D. C. (1997). Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes, 12*, 765–805.

Plaut, D. C., & McClelland, J. L. (1993). Generalization with componential attractors: Word and nonword reading in an attractor network. In *Proceedings of the 15th annual conference of the cognitive science society* (pp. 824–829). Hillsdale, NJ: Erlbaum.

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

Plourde, C. E., & Besner, D. (1997). On the locus of the word frequency effect in visual word recognition. *Canadian Journal of Experimental Psychology, 51*, 181–194.

Raaijmakers, J. G. W., Schrijnemakers, J. M. C., & Gremmen, F. (1999). How to deal with "the language-as-fixed-effect fallacy": Common misconceptions and alternative solutions. *Journal of Memory and Language, 41*, 416–426.

Rayner, K., McConkie, G. W., & Zola, D. (1980). Integrating information across eye movements. *Cognitive Psychology, 12*, 206–226.

Rumelhart, D. E., & McClelland, J. L. (1982). An interactive activation model of context effects in letter perception: Part 2. The contextual enhancement effect and some tests and extensions of the model. *Psychological Review, 89*, 60–94.

Seidenberg, M. S. (1990). Lexical access: Another theoretical soupstone. In D. A. Balota, G. B. Flores d'Arcaise, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 33–71). Hillsdale, HJ: Lawrence Erlbaum.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*, 521–568.

Seidenberg, M. S., & McClelland, J. L. (1990). More words but still no lexicon: Reply to Besneret al. (1990). *Psychological Review, 97*, 447–452.

Seidenberg, M. S., Petersen, A., MacDonald, M. C., & Plaut, D. C. (1996). Pseudohomophone effects and models of word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*, 48–62.

Seidenberg, M. S., Waters, G. S., Barnes, M. A., & Tanenhaus, M. K. (1984). When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior, 23*, 383–404.

Smith, J. E. K. (1976). The assuming-will-make-it-so fallacy. *Journal of Verbal Learning and Verbal Behavior, 15*, 262–263.

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donder's method. *Acta Psychologica, 30*, 276–315.

Tabossi, P., & Laghi, L. (1992). Semantic priming in the pronunciation of words in two writing systems: Italian and English. *Memory & Cognition, 20*, 315–328.

Tan, L. H., Hoosain, R., & Peng, D.-L. (1995). Role of early presemantic phonological code in Chinese character identification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 43–54.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition, 15*, 181–198.

Van Orden, G. C., Johnston, J. C., & Hale, B. L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experiment Psychology: Learning, Memory, and Cognition, 14*, 371–386.

Van Orden, G. C., Pennington, B. F., & Stone, G. O. (1990). Word identification in reading and the promise of subsymbolic psycholinguistics. *Psychological Review, 97*, 488–522.

Waters, G. S., & Seidenberg, M. S. (1985). Spelling-sound effects in reading: Time-course and decision criteria. *Memory & Cognition, 13*, 557–572.

Wike, E. L., & Church, J. D. (1976). Comments on Clark's "The Language-as-Fixed-Effect Fallacy". *Journal of Verbal Learning and Verbal Behavior, 15*, 249–255.

Wydell, T. K., Patterson, K. E., & Humphreys, G. W. (1993). Phonologically mediated access to meaning for Kanji: Is a rows still a rose in Japanese Kanji? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 491–514.