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The Influence of Orthography and Sentence Constraint on the Processing of Nouns in Japanese*

Kim Darnell[1], Julie Boland[2], Mineharu Nakayama[3]

Abstract: Utilizing a word-by-word reading paradigm, we investigated the role of orthographic familiarity in the processing of Japanese nouns by comparing the reading times of words that were *kanji* dominant (the *kanji* form is preferred by native speakers), *kana* dominant (the *kana* form is preferred), and orthographically neutral (both forms are equally acceptable). Target words appeared in *kana* or *kanji*, and were embedded in highly constraining (Experiment 1) or unconstraining (Experiment 2) carrier sentences. The results suggest that orthography does not affect reading time unless the sentence is highly constraining, in which case the most familiar orthography is faster.

For the most part, research on visual word recognition and sentence processing has focused on English and other alphabetic languages. Much less is known about how Japanese is processed. However, Japanese is an interesting language to investigate because, unlike English, it is head-final, allows pro-drop, and has three distinct orthographic systems: the logographic *kanji* and two *kana* syllabaries, *hiragana* and *katakana*. *Kanji* are logographic characters used to indicate meaning for content words, such as nouns and roots of verbs, adjectives and some adverbs. *Hiragana* is used for function words, the inflectional endings of verbs, adjectives and adverbs, and some nouns. *Katakana* is used primarily for representing loan words and onomatopoetic expressions. Thus, a single sentence may be composed of a mixture of all three orthographic systems.

The current paper investigates recognition of *kanji* and *hiragana* by varying the orthography and orthographic familiarity of target words in sentence contexts. In doing so, we hoped to discover how these variables affect reading time in typical Japanese sentences.

Kanji and *kana* differ in some important ways. The phonological readings for *kanji* are dependent on several factors, including the origin of the word in which a character appears, if the character is part of a compound, and the sentential context (see Figure 1). For *kana*, conversely, the readings are

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[1]Department of Linguistics, the Ohio State University

[2]Department of Linguistics and Department of Psychology, the Ohio State University

[3]Department of East Asian Languages and Literatures, the Ohio State University

completely invariant, each character representing a single, distinct mora[4] (Morton & Sasanuma, 1984). Furthermore, *kanji* are associated with particular meanings, while *kana* possess no inherent semanticity (Aoki, 1990; Elman et al., 1981; Hatta, 1978).

Character	in word of Chinese origin	in word of Japanese origin
性	sei, shou	saga

in different character compounds

性犯罪	seihanzai	'sex crime'
性分	shoubun	'disposition'

same character, different context

性	sei	'sex'
性	saga	'one's custom'

Figure 1. The different phonological readings of *kanji*

The differences between *kanji* and *kana* might have consequences on how the two types of orthographies access the lexicon. Of particular interest here are differences that might impact the speed of word recognition, and thus, reading time. For example, many have suggested that *kanji* access the lexicon by their physical form alone, while *kana* require the reader to recode phonologically before access is possible (Allport, 1979; Goryo, 1987; Inoue et al., 1979; Kimura, 1984; McCusker et al., 1981; Morton & Sasanuma, 1984). In order to test this claim empirically, one might assume that access via a direct, visual route is faster than access via the indirect, phonological route. This assumption predicts that words written *kanji* will be accessed more quickly than words written in *kana*. However, Besner & Hildebrandt (1987) found that words normally written in *katakana* were named more quickly when presented in *katakana* than *katakana* nonwords and words that normally appeared in *kanji* presented in *katakana*. They concluded that common *kana* can access the lexicon directly. Similar conclusions were drawn from empirical work by Hirose (1984, 1985) and Sasanuma and colleagues (Sasanuma et al., 1988) utilizing familiar *hiragana* words.

Assuming that direct access is faster than indirect access warrants caution on other grounds. When comparing across different visual stimuli, it is difficult to control early visual analysis time. Logographic characters can be very complex,

[4] A mora is defined as a sound unit which is produced for a certain length of time, and is sometimes equivalent to a syllable. In Japanese, it may be composed of a vowel, a consonant and a vowel, a single nasal, or a geminate consonant.

and it might take longer to perceive the relevant features of a word written in *kanji* as compared to one presented in *kana*. In this event, any difference in recognition time predicted by the different routes of access could be eliminated.

One goal of of the current project is to explore to what degree *kanji* and *kana* may be interchanged in text without significantly affecting processing time. A better understanding of the time-course of word recognition in the two orthographies will facilitate studies of Japanese sentence processing, particularly those using lexical ambiguity. To this point, such work has been inhibited due to the fact that the writing system has a specific means of distinguishing like tokens: words that would be ambiguous if written only in *kana* are instead written in *kanji* or a combination of *kanji* and *kana* (Aoki, 1990; Sasanuma et al., 1977).

But recall the evidence that familiar *katakana* and *hiragana* words were recognized faster than words that were unfamiliar in *kana* form. Orthographic familiarity, rather than orthography, might be the best determinate of reading speed. Interviews we conducted with native speakers show that within the lexical category of nouns, there are in fact words for which the *hiragana* form is dominant (i.e. native Japanese feel that the word most commonly appears in *hiragana* and is the most acceptable in this form), as well as those which are orthographically neutral. If we posit that the familiarity of the visual form, not whether it is logographic or syllabic, is the key to speed of lexical access, we can make some interesting predictions. The processing of *kana* dominant nouns should be slowed if they are presented in *kanji*. Moreover, nouns with no orthographic bias should display little difference in speed of facilitation between the *kanji* and *kana* forms. Such results would be particularly informative since other factors which affect processing speed, such as frequency (how often one is exposed to the word regardless of orthography) and concreteness (how salient an image one can create in association with the word), are identical for the *kanji* and *kana* forms of any given word, and therefore controlled variables.

The current study investigates the role of orthographic familiarity on the speed of lexical access by comparing response times for the *kanji* and *hiragana* forms of words with different script dominances embedded in context-biased sentences, where each target is preceded by lexical associates (Experiment 1), and non-biased sentences, where each target is semantically congruent but unpredictable (Experiment 2). The manipulation of context is likely to have two effects. The context-biased condition was designed to minimize any ambiguity for *kana* targets by insuring that, in the event that the target word has homophones, there is sufficient degree of contextual priming to eliminate the *kana* form being interpreted as having a meaning other than the one given by the corresponding *kanji*.. In doing so, however, we make the target words highly predictable compared to the non-biased condition. Predictability may well interact with familiarity if a biasing context leads the reader to expect the dominant orthographic form of a word.

Experiment 1

METHOD

Subjects Twenty native speakers of Japanese currently living in the greater Columbus area were used as subjects. All participants were between the ages of 18-40, were educated in Japan through high school, had lived in the U.S. for no more than five years, and had normal or corrected-to-normal vision. Each subject was paid a nominal fee for participating.

Apparatus The program for this experiment was written on the Macintosh KANJI TALK operating system and was presented on a Macintosh SEII monochrome screen. A customized response box was used to collect subject responses.

Stimuli The stimuli for this project came from three distinct groups of words: *kanji* dominant, where the *kanji* form is considered by native speakers to be the most familiar; *kana* dominant, where the *hiragana* form is most familiar; and orthographically neutral, where both forms are equally familiar. Data on words and orthographies were solicited via a questionnaire from fifteen native speakers representative of the intended subject pool. None of these individuals acted as subjects in this study.

All non-nominal items were eliminated from the collection of potential stimuli. The remaining words were then collapsed into a single list. This list was then redistributed for ranking of frequency of appearance of *kanji* and *kana* forms in everyday written material (1 = never 2 = very rarely 3 = rarely 4 = sometimes 5 = often 6 = very often 7 = all the time). Pairs in which the *kanji* form had a familiarity average of at least 2.5 points higher on the seven point scale than the *hiragana* form were considered *kanji* dominant, with the opposite requirement for *kana* dominant words. Orthographically neutral pairs were those in which the average scores for both scripts were within .5 of each other. All words were then rated for concreteness to control potential lateral differences in processing[5]; the characters with the highest ratings were given preference in their dominance category. The 10 pairs which best met both the frequency and concreteness criteria were chosen for each stimuli group. Group means are listed by dominance condition and orthography in Table 1 below.

	Kanji Dominant	*Kana* Dominant	Ortho Neutral
Kanji	6.88	2.64	5.33
Kana	2.61	5.83	5.41

Table 1. Mean familiarity ratings for *kanji* and *kana* forms of stimuli by dominance

Each stimulus was embedded in a sentence that contained "lexical associates"--other words which are strongly associated with the given item. For instance, consider (1). The target word is *rousoku* 'candle', its lexical associates are *tanjoubi* 'birthday', *keeki* 'cake', and *tatsu* 'to stand'. All of the associates appear before the target, affording a degree of contextual priming. In the event that the target word has homophones, this should eliminate the possibility of the stimuli written in *kana* being interpreted as having a meaning other than the one given by the corresponding *kanji*.

[5] Some tachistoscopic studies have suggested lateral preferences for *kanji* and *kana*, (Hatta, 1976, 1977, 1978; Hirata and Osaka, 1967; Sasanuma et al., 1977). However, these claims are contrary to English based experiments concerning the processing of abstract lexical items like adjectives and verbs (Elman et al., 1981) and concrete words like nouns (Caplan et al., 1974; Day, 1977; Ellis and Shepard, 1974; Hines, 1976, 1977; Shanon, 1979). Furthermore, Ohnishi and Hatta (1980) argue that the degree of concreteness of the *kanji* itself may control which hemisphere is dominant in processing. To avoid potential complications related to this issue, we elected to use only nouns that refer to concrete, easily visualized items.

(1) target: *rousoku* 'candle'
lexical associates: *tanjoubi* 'birthday', *keeki* 'cake', *tatsu* 'to stand'

tanjoubi-no	*keeki-no*	*ueni*	*taterareta*	*rousoku-wa*
birthday-Gen	cake-Gen	top on	stand-pass-past	candles-Top

kireini	*maru-o*	*egaiteita*
pretty	circle-Acc	arrange-pass-past

'The candles placed on the top of the birthday cake were arranged in a pretty circle.'

A questionnaire like that distributed by Tabossi (1988) was used to solicit associate words for each stimulus from 20 native Japanese speakers. The two to three most frequently suggested associates that could be used to produce a semantically congruous sentence were selected for each target. To minimize variables related to syntactic processing, every attempt was made to place the targets in the same syntactic position in each sentence, namely the direct object position. In some cases, however, the most acceptable place for the target was in the subject position; due to the head-final nature of Japanese, it was still possible to place the appropriate associates before the target in these instances.

Aside from the orthographic manipulation of the stimuli, the experimental sentences were presented in characters consistent with convention; the same carrier sentence was used for both the *kanji* and *kana* form of each stimulus.

There were two experimental lists. List 1 contained five stimuli from each dominance category in the *kana* form and five in the *kanji* form, while List 2 contained the same words in the opposite forms. To compensate for any lexical priming which might occur due to different stimuli having similar associates, or sentences containing words or *kanji* characters which might influence the reading speed of critical trials, each list had two orders. This allowed for a post-hoc analysis of order of sentence presentation, so that any such priming effects could be considered in the final interpretation of the data. Thirty-five distractor sentences of various types were added to each list to prevent subjects from developing a strategy of response to critical trials. (A full set of materials is available from the first author.)

PROCEDURE

Subjects were seated in front of the computer and shown the YES and NO keys on the response box; the YES key was always under the dominant hand. The sentences were presented in a self-paced, modified word-by-word format; subjects proceeded from word to word by pushing the YES key. Each word appeared in the center of the screen in 24 point font, surrounded by a one millimeter rectangle frame.

"Words" consisted of a noun and a particle, a modified noun and particle, an adjective or adjectival noun (possibly modified by an adverb) and inflectional ending, or a verb. The critical stimuli were always presented as a noun and a particle (see Figure 2).

	Japanese	Romanization	Gloss
Noun and particle	お母さんが	*okaasan ga*	mother-Nom
Modified noun and particle	髪の毛は	*kami no ke wa*	hair-Top
Adjectival noun with inflection	いろいろな	*iroiro na*	various
Verb	歩く	*aruku*	walk

Figure 2. Examples of words used in modified word-by-word task

At the end of each sentence, the subject saw a lexical item which he or she had to identify as either being or not being in that trial by pressing the YES or NO key; these probe words differed from the previously described phrases in that they were not followed by particles, and had the word "judge" above the frame. In critical trials, the probe words were chosen from among the lexical associates of the stimulus. This task was used as an accuracy filter, to make sure that subjects were reading each phrase presented to them.

One third of the trials were followed by comprehension questions to encourage subject attentiveness. To familiarize the subjects with the self-paced reading procedure, ten practice trials preceded the experimental trials.

After the experiment, each participant was given two questionnaires. The first tested the subject's ability to read the *kanji* forms of the 30 stimuli, to insure that he or she was actually capable of processing each stimulus in that orthography. The second questionnaire was identical to the one used to gather familiarity data for each stimulus (see *Stimuli*, above). Subjects' frequency ratings for the *kanji* and *kana* forms for each item were averaged and compared with the initial ratings to make sure there were no significant discrepancies.

Design This project had a design of 3(dominance) x 2(orthography) x 2(list) x 2(order), with dominance and orthography being within subject factors, and list and order being between subject factors.

RESULTS

Subjects had to be at least 90% accurate in probe word identification task for their reading times to be included in the experimental data. Five subjects, not included in the count of 20 given above, did not meet this criterion. Subjects who could not read a *kanji* form that had appeared in their version of the experiment had their reading times for that form eliminated from the data, since no lexical access could have taken place. These errors accounted for 22% of the *kanji* trials overall, but all fell within the *kana* dominant condition, which had a resulting error rate of 66%.

Means were taken of the reading times for the *kanji* and *kana* forms of each stimulus across subjects and items for each experimental condition (see Figure 3 for subject means). A range of acceptable reading times for each form of each item was defined as 2.5 standard deviations above and below the item mean.

Reading times for an item which fell outside of this range were replaced with the cut-off value. Three percent of the values were replaced in this way. The resulting sets of reading times were then analyzed by means of a three factor Analysis of Variance (ANOVA). A one-way post-hoc analysis (planned comparison) was also performed on the subject and item means for the *kanji* and *kana* forms in each dominance condition.

We found that subjects were able to read a word faster when it was presented in its dominant orthography, with the interaction of orthographic dominance and orthography of presentation significant by subjects [$F_1(2,34) = 4.946$, $p < .05$] and by items [$F_2(2,34) = 4.034$, $p < .05$]. As anticipated, there was no difference between the reading times in the neutral condition for *kanji* and *kana* by subjects [$F_1(1,17) = .029$, $p > .05$] or by items [$F_2(1,17) = .269$, $p > .05$)]. There was also, however, no significant difference between orthographies in the *kanji* dominant condition by subjects or items [$F_1(1,17) = 1.306$, $p > .10$; $F_2(1,17) = 1.998$, $p > .05$]. The reading times for *kanji* and *kana* were reliably different in *kana* dominant condition by subjects [$F_1(1,17) = 10.203$, $p < .05$], but not by items [$F_2(1,17) = .520$, $p > .05$].

Across orthographies, there was a main effect of orthographic dominance by subjects [$F_1(2,34) = 4.278$, $p < .05$], as well as a marginal effect of orthography of presentation [$F_1(1,17) = 3.164$, $p < .10$]. By items, however, there was only a marginal effect of dominance [$F_1(2,34) = 2.796$, $p < .10$]. *Kana* dominant words were read more slowly than *kanji* dominant words, which were read more slowly than orthographically neutral words.

The results of the familiarity ratings are summarized in Table 2 below.

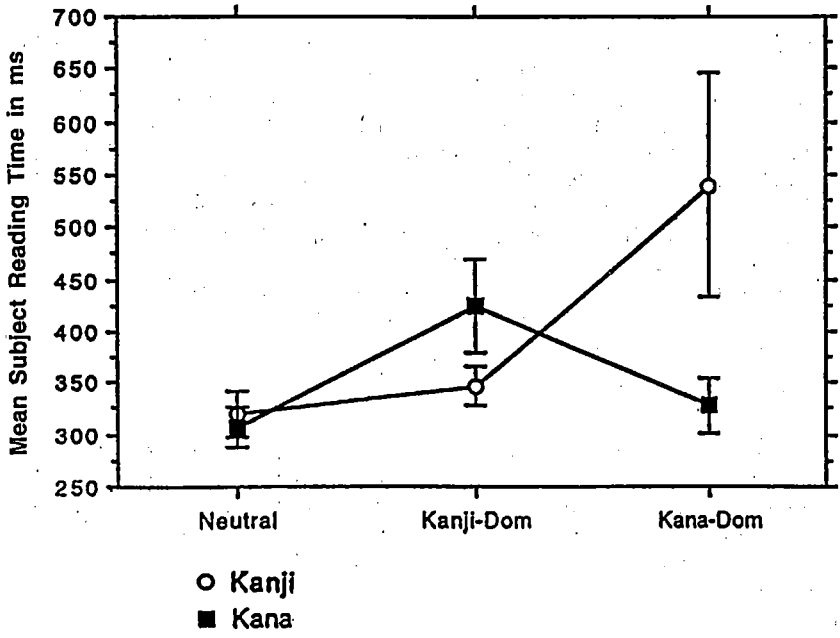

Figure 3. Mean reading time by orthography and orthographic dominance for Experiment 1, with standard error bars

	Kanji Dominant	*Kana* Dominant	Ortho Neutral
Kanji	6.74	2.40	5.03
Kana	1.85	6.10	4.67

Table 2. Experiment 1 mean familiarity ratings for *kanji* and *kana* forms of stimuli by dominance

DISCUSSION

Our results bring two points to the forefront. First, despite the physical differences between *kanji* and *kana*, it is possible for the two orthographies to be processed at the same rate when familiarity is controlled (as in the orthographically neutral condition). Second, the orthographic form that is most familiar is processed more readily than a less familiar form when the context is highly constraining. This is true even if the less familiar form is logographic and has more morphological content than the familiar script.

Still, there are two limitations to the conclusions we can draw. First, reading times for the *kanji* forms of words in the *kana* dominant condition appear drastically slower than *kana* times in the *kanji* dominant condition and have a huge range of standard error. This is undoubtedly due to the difficulty subjects had reading the unfamiliar kanji forms; further evidence for this difficulty is the large number of missing values in the cell caused by subjects' inability to read the *kanji* forms of certain words. In fact, post-hoc tests revealed that the difference between *kanji* and *kana* in the *kana* dominant condition was significant by subjects but not significant by items. Second, there is the possibility that the remarkably similar reading speeds for the *kanji* and *kana* forms of orthographically neutral words might be the result of the strongly biased context in which the stimuli were embedded. Somehow this biasing might neutralize the semantic advantage of the *kanji* form by heavily priming the stimulus and making it predictable, regardless of orthography of presentation. Conversely, the familiarity effect might be caused by the contextual bias. It is possible that the contexts are priming specific orthographies rather than abstract concepts. To investigate this issue, we performed a second experiment in which the stimuli were embedded in semantically plausible, but non-biased contexts.

Experiment 2

METHOD

Subjects There were twenty participants, different from those in Experiment 1, but from the same subject pool. Each was paid a nominal fee for their involvement.

Apparatus The same equipment was used as in Experiment 1.

Stimuli The targets from Experiment 1 were used in sentences that were not semantically biased toward the targets, but were restrictive toward the intended meaning (to eliminate potential interference from homophones). Consider example (2), below. As in (1), the stimulus is *rousoku* 'candle'. In this carrier, however, there are no lexical associates or other clues in the sentence which lead the reader to expect the stimulus in question.

(2) target: *rousoku* 'candle'

Yamamoto-san-wa	*chiisana*	*kawaii*	*nuigurumi-o,*
Miss Yamamoto-Top	little	cute	stuffed animals-Acc

soshite	*ruumumeito-no*	*Morii-san-wa*	*rousoku-o*
and	roommate-Gen	Miss Morii-Top	candles-Acc

atsumeteita
collect-past

'Miss Yamamoto collected cute little stuffed animals, and her roommate, Miss Morii, collected candles.'

Comparison of data produced in this experiment with that of Experiment 1 should clarify whether the contextual biasing in Experiment 1 produced an unnatural pattern of responses by helping subjects to predict the target. If the context has no reliable influence on the reading of the *kana*, then the response time patterns should replicate Experiment 1. Targets in this experiment were placed in the same syntactic position as their counterparts were in Experiment 1, although the syntactic structures of the respective sentences was not necessarily consistent. (A full set of materials is available from the first author.)

PROCEDURE

The same procedure was followed as for Experiment 1, including the completion of post-test questionnaires by each subject. The experimental design was also the same.

RESULTS

For Experiment 2, subject results forced us instead to set our lower limit for accuracy in the probe word identification at 85%. Five subjects, not included in the count of 20 given above, did not meet this new criterion. Again, subjects who could not read a *kanji* form that had appeared in their version of the experiment had their reading times for that form eliminated from the data. These errors accounted for 18% of the *kanji* trials overall, but all fell within the *kana* dominant condition, which had a resulting error rate of 53%.

Means were taken of the reading times for the *kanji* and *kana* forms of each stimulus across subjects and items for each experimental condition. Results for subjects are summarized in Figure 4. Reading times for each form of each item that did not fall within 2.5 standard deviations above and below the item mean were replaced with the cut-off value. Four percent of the values were replaced in this way. The final sets of reading times were analyzed in the same manner as in Experiment 1. The reading times for one *kana* dominant word, *jinmashin* 'nettle rash', were removed before analysis due to a grammatical error in the embedding sentence which occurred before the stimulus.

Contrary to our first study, the results from this experiment suggested that the script in which a word was presented had no effect on how quickly it was read by subjects, regardless of the word's orthographic dominance. There was a main effect of order by subject [$F_1(1,17) = 6.940$, $p < .05$] and by items [$F_2(1,17) =$

22.514, $p < .05$]. Orthographic dominance produced a marginal effect by subjects [$F_1(2,34) = 2.943$, $p < .1$] yet a main effect by items [$F_2(1,17) = 5.828$, $p < .05$]. By items there was also a marginal effect of orthography of presentation [$F_2(2,34) = 2.758$, $p < .1$], as well as a marginal interaction of orthographic dominance and order, [$F_2(2,34) = 2.789$, $p < .1$]. The (lack of) interaction for dominance and orthography of presentation by subjects is summarized in Figure 4.

There was no difference between the reading times in the neutral condition for *kanji* and *kana* by subjects, [$F_1(1,17) = .712$, $p > .05$], or by items, [$F_2(1,17) = 1.813$, $p > .05$]. There was also no significant difference between orthographies in the *kanji* dominant condition by subjects or items, [$F_1(1,17) = .005$, $p > .05$; $F_2(1,17) = .004$, $p > .05$], or in the *kana* dominant condition [$F_1(1,17) = 2.040$, $p > .05$; $F_2(1,17) = 1.972$, $p > .05$]. Across orthographies, *kana* dominant words were read more slowly than orthographically neutral words, which were read more slowly than *kanji* dominant words .

The results of the familiarity ratings are summarized in Table 3 below.

	Kanji Dominant	*Kana* Dominant	Ortho Neutral
Kanji	6.92	2.38	5.30
Kana	1.69	6.21	4.51

Table 3. Experiment 2 mean familiarity ratings for *kanji* and *kana* forms of stimuli by dominance

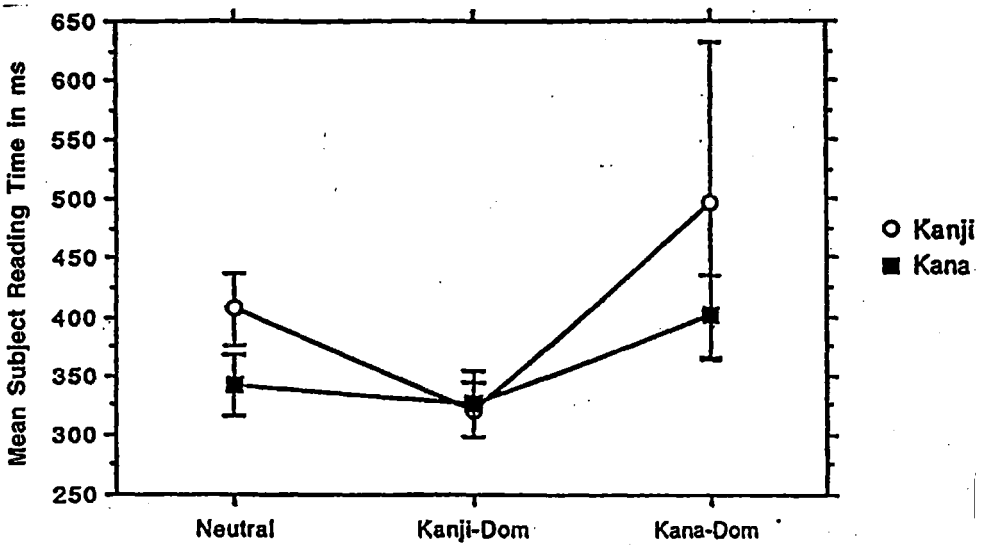

Figure 4. Mean reading time by orthography and orthographic dominance for Experiment 2, with standard error bars

DISCUSSION

In this follow-up experiment, we found no significant difference between the reading rates for *kanji* and *kana* words in any of the individual dominance conditions. This suggests that the familiarity effects observed in Experiment 1 were due to contextual priming. In fact, the pattern of results across the two experiments suggests that *kana* forms were inhibited in the *kanji* dominant condition in Experiment 1. This might well occur if contextual priming does not only stimulate particular items in the lexicon, but also suppresses the less familiar forms. Suppose that when an unfamiliar form of the lexical item is encountered in a sentence, the processor requires additional time to deal with the unanticipated input, almost as if a word which did not suit the context had been presented. Conversely, when the context is not predictable, all forms of a lexical item are equally available. From this we may posit that the familiar orthographic form of a word is recognized more readily because it meets more of the reader's expectations--expectations which appear to be extremely specific.

This "expectation hypothesis" is consistent with the findings of Altarriba et al. (1993), who found very similar patterns for lexical targets embedded in both highly constrained and unconstrained carrier sentences using eye-tracking and naming paradigms. In contrast to our work, however, their study utilized Spanish-English bilinguals as subjects, and manipulated the language of the target word. An effect of language was found only when the sentence was strongly biased toward the target and the target was of high frequency. Since low frequency words were not affected, it is unlikely that this effect arises at the level of visual encoding. They argued that sentence context can influence expectations for upcoming words at both the semantic/conceptual level and the lexical form level.

If we are capable of accessing lexical entries in both a nonspecific and orthography specific manner, then how do we shift between the two strategies? Having very specific requirements on the shape of the code necessary for semantic access to occur would be quite efficient if the range of code shapes was limited, as it tends to be in written language. For speech processing, however, such restrictions might pose problems considering the highly variant nature of the speech signals which correspond to a single lexical item. Is there some definable juncture, or is there a continuum of code shape flexibility? We are currently planning a series of small experiments to investigate the influence of the level of semantic biasing on the role of familiarity in visual word recognition.

SUMMARY

In sum, the results of Experiments 1 and 2 support the notion that *kanji* and *kana* can be processed at the same rate if familiarity is controlled or contexts are non-biasing. When contexts are highly constraining and contain multiple lexical associates, the orthographic form of a word which is most familiar is processed more readily than a less familiar form, even if the less familiar form has more morphological content than the familiar script. What is not clear, however, is precisely why the familiar orthographic form is processed more quickly. Experiment 2 suggests that, rather than familiar forms simply being easier to access than unfamiliar forms, unfamiliar forms fail to meet the reader's expectations of word shape and, as a result, require additional processing that manifests as a slowdown in response time.

Currently, there is not a single popular model of word recognition--including the logogen model (Morton, 1969), the search model (Forster, 1976), and the dual access model (Kleiman, 1975)--that can account for our data without a number of modifications. These models are all based on English, and assume the language of the speaker to be mono-orthographic. Since language acquisition is an innate human skill unrelated to the particular language itself, it does not seem reasonable

to posit prominent differences in the ways alphabetic, syllabic, and logographic writing systems access the lexicon. Accordingly, any model of word recognition that is truly generalizable should account equally well for input from each of these visual forms. The absence of such a universal model from the literature suggests that there is still a great deal of work to be done in the area of word recognition, and it is our hope that this study will initiate further investigation into this fascinating area of research.

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