Orthographic Influence in Processing *Katakana* and *Kanji* Nouns in Japanese[*]

Saori Wakita
The Ohio State University

Abstract
This study investigates how *katakana* and *kanji* nouns embedded in Japanese sentences are processed among native Japanese speakers by employing self-paced reading tasks. Darnell et al. (1994) found in their experiments that the orthographic type used for nouns did not affect reading times (RTs) when a noun appeared without its lexical associates in a sentence. This study extends their study to include another script, *katakana*, which was not tested in their study. Contrary to their findings, our experimental results revealed that RTs were faster when the target nouns were written in the more familiar script, such as *katakana* dominant words in *katakana*. Moreover, it was observed that script types did not change the RTs significantly with or without lexical associates. However, we still need a further investigation that directly compares *katakana* and *hiragana* before we can conclude that nouns in a familiar script in a sentence are always read faster.

Key words
Japanese scripts, *kanji*, *katakana*, orthography, self-paced reading experiments

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1. Introduction

The Japanese language employs four different script types: *kanji*, *hiragana*, *katakana*, and *romaji*. Moreover, a sentence is rarely written in only one script type. Due to these unique features, much less is known about how the language is processed, and it makes research in word and sentence processing interesting.

Using two script types, *kanji* and *hiragana*, Darnell et al. (1994) investigated the influence of script type and orthographic familiarity on the processing of nouns in sentences with and without lexical associates. The lexical associates are the nouns that activate other nouns, such as /neko/ 'cats' and /inu/ 'dogs.' They compared the reading times (RTs) of words that were in *kanji* dominant, *hiragana* dominant, and neutral script forms. Here, dominant means a word normally written in one preferred script type. They found that there was no significant difference in the RTs in either form under controlled environments where the stimulus sentence did not have priming. In other words, *kanji* and *hiragana* were processed at the same rate when there was no priming in a sentence (i.e., without lexical associates).

Their finding is surprising and important since, in many previous studies, researchers typically find reading speed differences between script types. The difference has been explained due to the routes each script takes, such as direct and indirect routes (Hatano et al. 1981, Morton and Sasanuma 1984, Shimamura 1987), or the familiarity (Besner and Hildebrandt 1987). Recently, functional magnetic resonance imaging (fMRI) has been used to examine what parts of the brain are activated while the reader reads *kanji* and *kana* (Thuy et al. 2004, Coderre et al. 2008, Buchweitz et al. 2009). Although the details of each experiment differed, the studies showed that the different scripts activated the same as well as different sites, which may lead to the observed difference. Also, many studies used isolated words in the experiments but did not examine the reading speed of the words embedded in sentences. Thus, how the nouns in different orthographies within a sentence with and without lexical priming affect the RT has not been investigated extensively yet. Therefore, it is important to study how they are processed by the readers.

In the current study, the RTs of the nouns in *kanji* and *katakana* embedded in sentences were measured using PsychoPy to compare the RTs. The purpose is to investigate Darnell et al.'s conclusions and test their suggestion that the orthographic type used for nouns does not affect RTs when target nouns appear within a sentence without their associates. We use the *katakana* script because many research studies assume that *katakana* and *hiragana* are processed in the same way since they are historically developed from the same script type, *kanji* (Hasegawa 2015:45), as well as them both being moraic. If the assumption is right, the nouns in *katakana* should also evoke similar results to those of Darnel et al. In that case, we can provide further support for their conclusion that different script types can be processed at the same rate when familiarity is controlled, and there is no priming. We can then also conclude that *hiragana* and *katakana* are processed similarly. Contrarily, if they are not processed similarly, we would expect to obtain dissimilar results. Then we would need to investigate further if the two scripts are processed differently or if other factors could affect the RT difference.

The organization of this paper is as follows: Section 2 briefly reviews previous studies on Japanese script processing. Section 3 discusses our experimental design and procedure. Section 4 presents the results of the experiments. Finally, the last section is a discussion of the conclusion.

2. Previous Lexical Processing Studies

It is typical for researchers to find an RT difference between *kanji* and *kana*. Many suggest that *kanji* access the lexicon without coding phonologically (Allport 1979, Hatano et al. 1981, Inoue et

al. 1979, Kimura 1984, Morton and Sasanuma 1984). These scholars' results support that there are different routes to accessing the lexicon depending on the script type. The interpretation of having at least two routes is based on the idea that orthography might determine the reading speed.

However, Besner and Hildebrandt (1987) instead suggest that there might be a familiarity effect on reading words. They found that words usually written in *katakana* were named quicker when presented in *katakana* than non-real Japanese words written in *katakana* and words written in *katakana* normally written in *kanji*. They concluded that common *katakana* words could access the lexicon directly and more quickly. Their results indicate that orthographic familiarity affects processing time.

Darnell et al. advanced their hypothesis by conducting experiments and revealed the need for further study on script familiarity and word processing in a sentence. They compared the reading times of words that were *kanji* dominant, *hiragana* dominant, and script neutral. What they meant by "*kanji* dominant" was that the *kanji* form was generally preferred by native speakers of Japanese, and that "script neutral" meant words that were considered natural when written in either *kanji* or *hiragana* script. They predicted that if orthographic familiarity determines reading speed, then the *hiragana* dominant words written in *hiragana* should be read faster than when they are instead written in *kanji*. Conversely, it was predicted that those in the unfamiliar script type would have longer RTs than those in the familiar script type.

In their study, they conducted two experiments. In Experiment 1, each stimulus sentence had lexical associates. Then, Experiment 2 was conducted similarly but without lexical associates. The purpose of the second experiment was to investigate whether semantically closely related words made the reader anticipate a certain script type in the target word. For instance, the target word in test sentence (1) is *roosoku* 'candle', and its lexical associates are *tanjoobi* 'birthday', *keeki* 'cake', and *tatsu* 'to stand.' All of the lexical associates appear before the target word in Experiment 1, affording a degree of contextual priming.

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

tanjoobi-no	keeki-no	ue-ni taterareta	roosoku-wa
birthday-GEN	cake-GEN	top on stand-PASS-PAST	candles-TOP

kireini	maru-o	egaiteita
pretty	circle-ACC	arrange-PAST

'The candles placed on top of the birthday cake were arranged in a pretty circle.'
(Darnell et al. 1994:96)

Experiment 1 showed that participants could read words faster when they were written in their dominant script. The orthography-neutral words did not show a significant difference in reading time between their *kanji* and *hiragana* forms.

The motivation for Experiment 2 was to find out if lexical associates could make the processing of the participant more ready for dominant items than for less familiar items. The following sentence is an example sentence from their second experiment:

(2) target: *roosoku* ‘candle’

Yamamoto-san-wa	chiisana	kawaii	nuigurumi-o,
Miss Yamamoto-san-TOP	little	cute	stuffed animals-ACC

soshite	ruumumeito-no	Morii-san-wa	roosoku-o	atsumeteita.
and	roommate-GEN	Miss Morii-TOP	candles-ACC	collect-PAST

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

(Darnell et al. 1994:100)

Sentence (2) has the same target word but does not include lexical associates. The results from Experiment 2 showed that the script in which a target word was presented without lexical associates did not affect how quickly the participants could read it, regardless of the word’s orthographic dominance.

These two experiments suggest that *kanji* and *hiragana* can be processed at the same rate when there is no priming. In other words, the readers could read nouns in the two script forms at the same rate when they did not encounter any lexical associates in the stimulus sentences.

If *hiragana* and *katakana* are processed in the same way, and the orthography is not the determinant of the RT, we should not see a significant difference between the two scripts in RTs when there is no priming. It would be best to investigate whether *katakana* shows similar results to what *kanji* and *hiragana* showed in Darnell et al.’s experiments. If it does, we can conclude that orthographic type does not affect RTs without lexical associates when familiarity is controlled. This, in turn, provides evidence that *hiragana* and *katakana* scripts are processed in a similar way.

3. Experiment

3.1 Research purpose

Our purpose is to examine the validity of the suggestion made by Darnell et al. that orthographic familiarity, rather than orthographic type, might be the best determinant of reading time. Our experimental questions are: (I) whether the RT is faster for words written in a familiar script, *katakan*a, in the *katakana*-dominant condition when a lexical associate is embedded in a stimulus sentence, as Darnell et al. found for the target nouns in *kanji* and *hiragana* in *kanji*-dominant and *hiragana*-dominant conditions respectively, and (II) whether the RTs are the same for words written in familiar and unfamiliar script forms when there are no lexical associates in the sentences.

3.2 Participants

Forty native speakers of Japanese participated in this study. They were between the ages of 18 and 40, had received education through high school in Japan, had lived abroad for less than five years, or were currently living in Japan. Each participant was paid a nominal fee for their participation. They participated online due to the Covid-19 pandemic.

3.3 Stimuli and sentence structure

The stimuli for this study came from two distinct groups of nouns: orthographically neutral, where both script forms, *katakana* and *kanji*, are equally familiar, and *katakana* dominant, where the *katakana* form is most familiar.

A summary of the contents of each of the two experiments is as follows: (a) 20 target nouns embedded in short, simple Japanese sentences like (3), (b) 20 filler sentences, (c) two practice sentences, and (d) 12 questions about either the target or the filler sentences. Since the actual

stimuli used were inaccessible, new stimuli were created.

There were two versions of the survey, and each participant evaluated the words in either versions A or B. They contained the same words with fillers and target words. When a target word appeared in *katakana* in version A, the same word appeared in the same spot in *kanji* in version B.

The target nouns were chosen by a survey given to 16 native speakers of Japanese who did not participate in the main experiments. They rated the word familiarity using a scale of 1 (unfamiliar) to 7 (familiar). The pairs in which the *katakana* form had a familiarity average of at least two points higher on the seven-point scale than the *kanji* form were designated as *katakana* dominant. Orthographically neutral pairs were those in which the average scores for both scripts were less than one point from each other.

The words chosen were 20 nouns shown in Table 1. We have four lists to replicate the original experimental environments in Darnell et al. (1994), in which Lists 1 and 2 have lexical associates (Experiment 1), while Lists 3 and 4 do not (Experiment 2).

Table 1. Words used in the main experiment

List 1/List 3		List 2/List 4	
Neutral list	*Katakana* Dominant	Neutral list	*Katakana* Dominant
1. 煙草 /tabako/	11. タンス /tansu/	1. タバコ	11. 箪笥
2. 蟻 /ari/	12. ネギ /negi/	2. アリ	12. 葱
3. 猫 /neko/	13. ブリ /buri/	3. ネコ	13. 鰤
4. 海老 /ebi/	14. アワビ /awabi/	4. エビ	14. 鮑
5. 葡萄 /budoo/	15. ラーメン /raamen/	5. ブドウ	15. 拉麺
6. ホタル /hotaru/	16. 鯱 /syati/	6. 蛍	16. シャチ
7. カッパ /kappa/	17. 海豚 /iruka/	7. 河童	17. イルカ
8. イチゴ /itigo/	18. 雀蜂 /suzumebati/	8. 苺	18. スズメバチ
9. サワラ /sawara/	19. 蒲公英 /tanpopo/	9. 鰆	19. タンポポ
10. バラ /bara/	20. 大蒜 /nin'niku/	10. 薔薇	20. ニンニク

Following Darnell et al., we inserted the target nouns into sentences with lexical associates in Lists 1 and 2, and without them in Lists 3 and 4. Stimulus sentence (3) below shows the lexical associate word *sake* (in Lists 1 and 2) or the non-lexical associate word *nuno* (in Lists 3 and 4), prior to the target word *tabako.*

(3) target: *tabako* 'cigarette'
lexical associates: *sake* 'sake'

Yamamoto-san-wa	yuumeide	jooshitsuna	sake (*nuno*)-o soshite
Yamamoto-san-TOP	famous	high quality	sake (cloth)-ACC and

ruumumeeto-no	Morii-san-wa	**tabako**-o	yooishita.
roommate- GEN	Morii-san-TOP	cigarette-ACC	prepared

'Yamamoto-san prepared a famous, high-quality sake, and his roommate Morii-san prepared cigarettes.'

We only used one lexical associate in each stimulus sentence, though Darnell et al. included three

associates. This allowed us to place every target word in the same position for all four lists.

3.4 Lexical associates for Lists 1 and 2

For lexical associates, we used Tsukuba Web Corpus to solicit words. Using this corpus, we examined what nouns frequently co-occurred with our target nouns and assigned them as the lexical associates to the target nouns. Below are not all, but some the examples of the target words and lexical associates selected from the corpus:

Table 2. Examples of target and lexical associate words

Target Word	Lexical Associate
/tabako/ 'cigarette'	酒 /sake/ 'sake'
/ari/ 'ant'	キリギリス /kirigirisu/ 'grasshopper'
/neko/ 'cat'	犬 /inu/ 'dog'
/ebi/ 'shrimp'	カニ /kani/ 'crab'
/budoo/ 'grape'	りんご /ringo/ 'apple'

For Lists 3 and 4, we used nouns that were not registered as frequently co-occurring words in the corpus. This assumes that a non-lexical-associate word is unlikely to invoke our target word as a prime when it is not registered as a co-occurring word in the corpus.

Table 3. Examples of target and non-lexical associate words in Lists 3 and 4

Target	Non-lexical associate
/tabako/ 'cigarette'	布 /nuno/ 'cloth'
/ari/ 'ant'	蓋 /huta/ 'lid'
/neko/ 'cat'	靴 /kutu/ 'shoes'
/ebi/ 'shrimp'	筆 /hude/ 'brush'
/budoo/ 'grape'	豆腐 /toohu/ 'tofu'

3.5 Procedure

Using PsychoPy3 for the self-paced reading task, participants were instructed to access the website Pavlovia using their own computers with a keyboard. On the website, each segment of the sentence was displayed, one segment at a time. Each segment consists of a noun and a particle, an adjective or an adjectival noun with an inflectional ending, or a verb with an inflected ending. The target stimuli, the target noun, was always presented as a noun and a particle as in 猫を (/neko o/, 'cat-Accusative case particle'). The participants were asked to read as fast as they could at the beginning. There were 12 yes-no questions, which appeared at random times. After the main test session, participants took an online *kanji* quiz to see if they could actually read the *kanji* that appeared in the session. For details of the experimental material and design, see Wakita (2022, 2023).

4. Results

Forty participants' RTs were included for data analysis without the practice sentences: eleven for List 1, nine for List 2, and ten each for Lists 3 and 4.

The average RT per mora was determined for each participant based on their own RTs for all stimulus sentences in the list, and a range of acceptable RTs for each orthography of each noun was defined as one's 2.5 standard deviations (SD) above and below the item mean. RTs for the target items that fell outside of this 2.5 SD range were replaced with the cut-off value for each person. For the participants who could not read a *kanji* character, their reading times for those words were replaced by their 2.5 SD above the item mean RT.

4.1 Results for Experiment 1 (Lists 1 and 2)

This section answers the first question: (I) whether the reading time is faster for words written in a familiar script, *katakana*, in the *katakana*-dominant condition when a lexical associate is embedded in the stimulus sentence, as Darnell et al. found for the target nouns in *kanji* and *hiragana* in *kanji*-dominant and *hiragana*-dominant conditions respectively. A summary of the experiment with Lists 1 and 2 using lexical associates in the test sentences is presented in Table 4.

Table 4. Mean RTs per mora in Lists 1 and 2 (n = 400)

		Dominance		
		Neutral	*Katakana*	Ave. (per second)
Script	*Kanji*	.2230 (L1: .2565, L2: .1973)	.2521 (L1: .2685, L2: .2321)	.2376
	Katakana	.1948 (L1: .1918, L2: .1985)	.1797 (L1: .2090, L2: .1439)	.1873
	Ave.	.2089	.2159	.2124

The two lists were combined and the average RTs of each individual and each item were analyzed by a two-factor Analysis of Variance (2 script types x 2 dominance types).[1] The script type was significantly different by both subject and item analyses [$F_1(1,19) = 39.97$, $p < 0.001$, $F_2(1,18) = 18.31$, $p < 0.001$] whereas the dominance type was not [$F_1(1,19) = 0.001$, $p = 0.97$, $F_2(1,18) = 0$, $p = 0.99$]. There was a significant interaction between the effects of script and dominance types [$F_1(1,19) = 12.59$, $p = 0.002$, $F_2(1,18) = 5.93$, $p = 0.025$]. The significant difference in both script and script-dominance interaction suggests that *katakana* words were read faster than *kanji*.

We also conducted an independent samples t-test. Within each dominance condition, the two RTs in the neutral condition were not significantly different [$t(19) = 1.384$, $p = 0.182$], while the target words written in *kanji* significantly differed from the target words written in *katakana* in the *katakana*-dominant condition [$t(19) = 5.672$, $p < 0.001$].

Additionally, within each script type condition, the mean RTs for target words written in *kanji* in the neutral condition and *katakana*-dominant condition were tested. The two RTs of the *kanji* script in the two conditions, neutral and *katakana*-dominant, were not significant [$t(19) = -1.361$, $p = 0.189$], and the two RTs of the *katakana* script in the two conditions were not significant either [$t(19) = 1.384$, $p = 0.182$].

[1] Lists 1 and 2 were reversed in script type, but due to the imbalance in the participant numbers, we combined them and analyzed the data so that the entire group became comparable to the Lists 3 and 4 group, i.e., 20 participants.

4.2 Results for Experiment 2 (Lists 3 and 4)

The experiment conducted using Lists 3 and 4 was to answer (II) whether the reading time is the same for words written in familiar and unfamiliar scripts when there is no lexical associate in the sentence. A summary of the results is provided in Table 5.

Table 5. Mean RTs per mora in Lists 3 and 4 (n = 400)

		Dominance		
		Neutral	*Katakana*	Ave.(second)
Script	*Kanji*	.2386	.2915	.2650
		(L3: .2517, L4: .2255)	(L3: .2724, L4: .3104)	
	Katakana	.2250	.2185	.2218
		(L3: .2019, L4: .2482)	(L3: .2248, L4: .2122)	
	Ave.	.2318	.2550	.2434

Lists 3 and 4 were combined and the average RTs of each individual and each item were analyzed by a two-factor Analysis of Variance (2 script types x 2 dominance types). The script type was significantly different by both subject and item analyses [$F_1(1,19) = 10.48$, $p = 0.004$, $F_2(1,19) = 5.58$, $p = 0.029$] whereas the dominance type was significantly different by subject [$F_1(1,19) = 4.47$, $p = 0.05$], but not by item [$F_2(1,18) = 0.94$, $p = 0.345$]. There was a significant interaction between the effects of script and dominance types [$F_1(1,19) = 5.58$, $p = 0.029$, $F_2(1,18) = 12.13$, $p = 0.003$]. The significant difference in both script and script-dominance interaction suggests that *katakana* words were read faster than *kanji*. This is the same finding as in Lists 1 and 2.

We also ran an independent samples t-test on Lists 3 and 4 that showed that there was no difference between the RTs of the two script forms in the neutral condition [$t(19) = 0.898$, $p = 0.381$], while there was a significant difference between the RTs of the two forms for the *katakana*-dominant condition [$t(19) = 3.460$, $p = 0.003$].

As with Lists 1 and 2, we compared two different dominant conditions within each script type condition in Lists 3 and 4. The two RTs of the *kanji* script in the two conditions were significant [$t(19) = -3.010$, $p = 0.007$], while the two RTs of the *katakana* script in the two conditions were not significant [$t(19) = 0.414$, $p = 0.684$].

4.3 Comparison of List 5 (Lists 1 and 2) and List 6 (Lists 3 and 4)

Finally, we compare the two experimental results, the one with lexical associates and the other without. We labeled the data from Lists 1 and 2 as List 5 and the data from Lists 3 and 4 as List 6. The RTs were analyzed by a three-factor Analysis of Variance (2 list types x 2 script types x 2 dominance types). The list types were not significantly different by subject [$F_1(1,38) = 0.95$, $p = 0.335$] but were significantly different by item [$F_2(1,18) = 21.25$, $p < 0.001$]. The script type was significantly different by both subject and item analyses [$F_1(1,38) = 38.47$, $p < 0.001$, $F_2(1,18) = 46.27$, $p < 0.001$] whereas the dominance type was not significantly different [$F_1(1,38) = 2.19$, $p = 0.147$, $F_2(1,18) = 0.28$, $p = 0.606$]. There was not a significant interaction between the effects of the list and script [$F_1(1,38) = 0.67$, $p = 0.419$, $F_2(1,18) = 0.62$, $p = 0.44$]. There was not a significant list and dominance interaction by subject [$F_1(1,38) = 2.34$, $p = 0.135$], but it was marginally significant by item [$F_2(1,18) = 4.02$, $p = 0.06$]. There was a significant interaction between the effects of script and dominance types [$F_1(1,38) = 15.92$, $p < 0.001$, $F_2(1,18) = 17.79$, $p < 0.001$].

There was not a significant interaction among the effects of list, script and dominance [$F_1(1,38) = 0.02$, $p = 0.877$, $F_2(1,18) = 0.02$, $p = 0.887$].

Additionally, we ran an independent samples t-test on Lists 5 and 6 to determine if the mean of the RTs of the target words written in *kanji* and *katakana* differed from those in each list. Both script forms were not significantly different between the lists, *kanji* [$t(19) = -1.047$, $p = 0.308$] and *katakana* [$t(19) = -1.619$, $p = 0.122$]. The RTs of the neutral condition between the two lists were not significantly different [$t(19) = -0.882$, $p = 0.389$].

5. Discussion and conclusion

Summarizing our analysis, from a two-factor ANOVA, we found a significant difference in script type between Lists 1 and 2, and between Lists 3 and 4 by subject and item. We did not find a significant difference in script dominance type by subject and item in Lists 1 and 2, nor by item in Lists 3 and 4. There was a significant interaction between the effects of script and dominance types in both Lists. Our overall statistical analysis results indicate that the target words written in *katakana* were read faster than the target words written in *kanji* by our participants. We can say RTs reflected the familiarity ratings.

To answer questions (I) and (II), we created two new lists, Lists 5 and 6, as mentioned above. There was no significant difference in the list types; the interaction between the effects of the list and script; the interaction between the list and dominance; nor the interaction among the effects of the list, script, and dominance. This suggests that sentences with and without lexical associates would not affect the RTs when familiarity is controlled.

For question (I), we can conclude that RT is faster when the target words are written in the familiar orthography *katakana* in the *katakana*-dominant condition. This outcome goes along with the findings of Besner and Hildebrandt (1987).

For question (II), we found that the RTs were not the same for words written in familiar and unfamiliar scripts, even when there was no lexical associate in the sentence. For instance, *kanji* was read slower in Lists 3 and 4. From the independent samples t-test, we also found a difference between *kanji* and *katakana* scripts within the *katakana*-dominant condition. We can conclude that the familiar script form was read faster.

In conclusion, although we did not find similar results to those of Darnell et al., our results do support the findings and claims by Besner and Hildebrandt that script familiarity needs to be considered when we think about how words are processed. Finally, it is still possible that we did not find similar results to those of Darnell et al. due to the difference in our stimuli, or possibly our Japanese readers did not process *katakana* and *hiragana* in the same way. We need a further investigation to directly compare *katakana* and *hiragana* and answer whether the readers process nouns written in *katakana* and *hiragana* in the same way before we can conclude that Japanese native speakers read nouns embedded in a sentence faster when they are written in any familiar script form.

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Data and Tools

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wakita.2@osu.edu