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The effect of morphemic homophony on the processing of Japanese two-kanji compound words

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Abstract. Two experiments investigated the effect of kanji morphemic homophony on lexical decision and naming. Effects were examined from both the left-hand and right-hand positions of Japanese two-kanji compound words. The number of homophones affected the processing of compound words in the same way for both tasks. For left-hand kanji, fewer morphemic homophones led to faster lexical decision and whole-word naming. For right-hand kanji, the number of morphemic homophones did not affect either lexical decision or naming. This effect of homophonic density suggested that, when a kanji-compound word is to be processed, phonological information of its kanji constituents is automatically activated and reverberates back to generate a series of orthographic representations of kanji morphemic homophones, but not in a completely parallel fashion.

Key words: Kanji reading, Lexical decision, Morphemic homophones

Introduction

Some Japanese words are comprised of single character morphemes (kanji) having a high density of homophony. Because of this, it is commonly believed that phonology does not play as important a role in reading and writing as does orthography. Despite this belief, Japanese native speakers often make mistakes when writing a kanji character which shares its sound with many others. Hatta, Kawakami and Tamaoka (1998, 2002) reported that phonologically related writing errors (e.g., 社回 /sja kai/ for 社会 /sja kai/) outnumber those related to orthography (e.g., 委節 /i setju/ for 季節 /ki setju/). This finding suggests that phonology of Japanese kanji comes into play even in tasks which are ostensibly devoted to the orthographic aspect of kanji writing. Given this, the question arises as to whether or not a two-way interaction between orthography and phonology occurs when Japanese kanji with a high density of kanji homophony are processed, and more specifically, how the orthographic and phonological representations of kanji are related in the mental lexicon.

Mapping of a single kanji morpheme to multiple sounds

Kanji pronunciations can be divided into two types: the On-reading derived from the original Chinese pronunciation, and the Kun-reading originating from the Japanese way of reading kanji (see details in Kaiho & Nomura, 1983; Morton & Sasanuma, 1984; Tamaoka, 1991, 2003; Wydell, Butterworth & Patterson, 1995; Wydell, Patterson & Humphreys, 1993). However, this mixture of material with two phonological origins were usually distinguished by lexical items, rather multiple pronunciations of a single Japanese kanji were created by On-readings.

The Japanese first encountered the written Chinese language around the end of the fourth and the beginning of the fifth century (Hadamitzky & Spahn, 1981; Miller, 1967; Seeley, 1984; Tsukishima, 1979). They borrowed heavily from Chinese, but did not adopt the four tones which exist in the standard Mandarin form of the Chinese language. During this period of contact with China, the Japanese imitated the sounds of Chinese characters without the tones from the Chinese sound system. As a result of this, and the movement of the capital cities during different periods of China's political history, various Chinese dialects and differing types of pronunciation were borrowed (Miller, 1967; Sato et al., 1978). Systems were labeled according to the names of the Chinese dynasties in political power during each period when Japan interacted with China. Kanji pronunciations of On-readings are further classified into three types: namely, *Go*-on, *Kan*-on and *To*-on (formerly called *So*-on). These three different systems of pronunciation simultaneously exist in the On-readings of kanji used in modern Japanese.

In dispensing with the Chinese tones and adapting three different sound systems from China, the Japanese created a great number of multiple On-readings for kanji. According to the *Database for the 1945 Basic Japanese Kanji, 2nd edition* (Tamaoka, Kirsner, Yanase, Miyaoka & Kawakami, 2002), the total number of kanji which have only one pronunciation is 699 (667 kanji with a single On-reading and 32 kanji with a single Kun-reading). This is 35.94% of the 1945 basic Japanese kanji. Kanji which have only On- or only Kun-readings, regardless of the number of pronunciations, total 779 (739 for On-reading and 40 for Kun-reading), or 40.05% of the 1945 basic Japanese kanji. In other words, although it is a commonly-held notion that a kanji has both an On-reading and a Kun-reading, only 1166 kanji or about 59.95% of the 1945 basic Japanese kanji have both types of pronunciations.

Let us examine one of the 1166 kanji which has multiple readings of both the On and Kun types. As shown a mapping of a single kanji to multiple sounds in Figure 1, the kanji 木 (meaning 'tree' in English) is

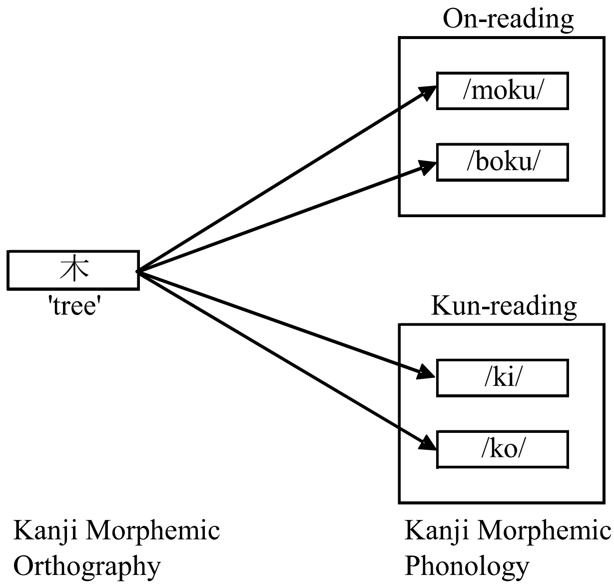

Figure 1. Mapping of a single kanji to multiple sounds.

pronounced as /moku/ and /boku/ in On-reading and /ki/ and /ko/ in Kun-reading. When the orthographic representation of 木 is activated, its activation will spread not only into its semantic representation of 'tree' but also into its phonological representations. The activation of 木 could possibly and automatically spread to all four possible pronunciations although its activation levels will differ from one to another. In this type, the direction of activation moves from orthography to phonology.

For kanji, there is no systematic mapping from orthography to phonology in the same manner seen in alphabetic languages (Wydell et al., 1993; Wydell et al., 1995). Thus, one can assume that in a two-kanji compound each kanji will be read as a part of the whole word, and not as a single kanji morpheme unit. If this is true, multiple pronunciations held by kanji would have no effect on the naming of two-morpheme compound words because pronunciations would be identified at the unit of a word, not at the kanji morpheme level. Even if the spread activation from orthography to phonology does occur, it would not have a strong effect on lexical decision and naming of two-morpheme compound words constructed by two kanji units with multiple readings.

Wydell et al. (1995) investigated kanji activations from orthography to phonology. As depicted in Figure 1, a kanji 木 ('tree') is pronounced /ki/ and /ko/ in Kun-reading while it is also read /moku/ and /boku/ in On-reading. According to Wydell et al. (1995), these kanji with multiple pronunciations do not have any effect upon the naming of two-kanji compound words: the sounds of /moku/, /boku/, /ki/ and /ko/ do not have any effect on the naming of its compound words such as 木材 ('lumber'/moku zai/), 木刀 ('a wooden sword' /boku toR/), 木戸 ('a gate' /ki do/) and 木陰 ('the shade of a tree' /ko kage/). Then, assuming that the claim by Wydell et al. (1995) is correct, exhaustive activations from orthography to phonology should not occur in kanji phonological processing for the naming task of two-kanji compound words.

Despite such an intensive study by Wydell et al. (1995), a study of Kayamoto, Yamada and Takashima (1998) suggested the existence of print-and-sound consistency effects at the kanji level. This study's claim is based upon a naming task of single kanji morphemes. In Experiment 1, Kayamoto et al. found that kanji with multiple pronunciations are named slower than kanji with a single pronunciation. However, kanji with multiple pronunciations naturally have multiple correct sounds as in 数 pronounced as /kazu/ or /suR/. The speed and accuracy of these kanji were compared to others with a single sound as in 点 pronounced as /teN/. Under these conditions, native Japanese speakers must suppress one of the correct pronunciations of kanji with multiple-readings so it is naturally expected that they will have higher error rates and slower response times in naming these kanji. As expected, they found the results of consistency effects at the kanji level.

In Experiment 2, Kayamato et al. (1998) further investigated consistency effects using only kanji with a high frequency of written occurrence. This time, they obtained a conflicting result as there were no consistency effects at the kanji level. Subjects were able to name a kanji with a single pronunciation as fast as a kanji with multiple pronunciations. This could be explained by the fact that kanji with a high frequency of written occurrence have an especially strong connection between kanji orthography and one of their sounds. It could be assumed that one of the sounds in a single kanji with multiple pronunciations must have an equally high frequency of occurrences as another kanji with a single sound.

It is also interesting to note that some high-frequency kanji used by Kayamoto et al. (1998) had highly concrete and easily imaginable meanings when sounded in Kun-readings such as 夏 /natu/ meaning 'summer', 窓 /mado/ meaning 'window', 旗 /hata/ meaning 'flag'. As Hirose (1998), Kaiho and Nomura (1983) and Nomura (1978) suggest, Kun-readings are strongly attached to kanji meanings, especially when those kanji are presented as a single kanji. Therefore, subjects are likely to pronounce a single kanji by way of its Kun-reading which represents a word with meaning by itself instead of having to combine with other kanji. Thus, the speed of the naming of a single kanji with multiple sounds should be further examined based upon frequencies of kanji sounds and semantic independency of kanji Kun-readings.

There is a fundamental difference in the stimulus items used by Wydell et al. (1995) and Kayamoto et al. (1998) to test kanji consistency effects. Wydell et al. used two-kanji compound words for naming whereas Kayamoto et al. used single kanji. Consequently, regardless of the findings of Kayamoto et al. (1998), the study done by Wydell et al. (1995), indicating no effects of kanji orthography-to-phonology exhaustive activations at the morpheme level, remain intact. The present study also used two-kanji compound words as stimulus items in Wydell et al. (1995). Nevertheless, taking the argument of kanji multiple exhaustive activations as indicated by Kayamoto, et al. (1998) into consideration, experiments in the present study saw fit to control the number of kanji pronunciations constructing two-kanji compound words, and focused its research onto a single sound shared by multiple kanji orthography.

Mapping of a single sound to multiple kanji morphemes

Although Japanese kanji often have multiple pronunciations including both the On- and Kun-readings, multiple kanji sharing the same sound are much greater and more commonly observed in On-readings. By the ninth grade, Japanese speakers will have mastered the 1945 basic Japanese kanji. Even within this range of fundamental kanji, the *Database for the 1945 Basic Japanese Kanji* (Tamaoka et al., 2002; Tamaoka & Makioka, 2004) shows that the most-shared sound was /sjoR/[1] which was represented by 65 kanji (all On-reading) among the 1945 basic kanji. This is approximately 3.3% of the total number of basic kanji. The sound /koR/, having 64 On-readings and one Kun-reading, also showed the same number of kanji symbols as the sound /sjoR/. Almost all of these homophonic sounds are found to be On-readings.

The possible connection from a single sound to multiple kanji morphemes is illustrated in Figure 2. The sound /ka/ in morphemic phonology can be written as various kanji such as 火 ('fire'), 化 ('chemical'), 科 ('section'), 花 ('flower'), 家 ('house') and 蚊 ('mosquito'). All these kanji could be read as the sound /ka/ (most exclusively On-readings). Because such a great number of kanji can represent the same sound, it would seem that their pronunciation is not a reliable means of accessing their semantic information. It is not surprising that some previous studies on the Japanese language (e.g., Goryo, 1987; Kimura, 1984; Kimura & Bryant, 1983; Saito, 1981; Sasanuma, 1986; Seidenberg, 1985) assumed that kanji

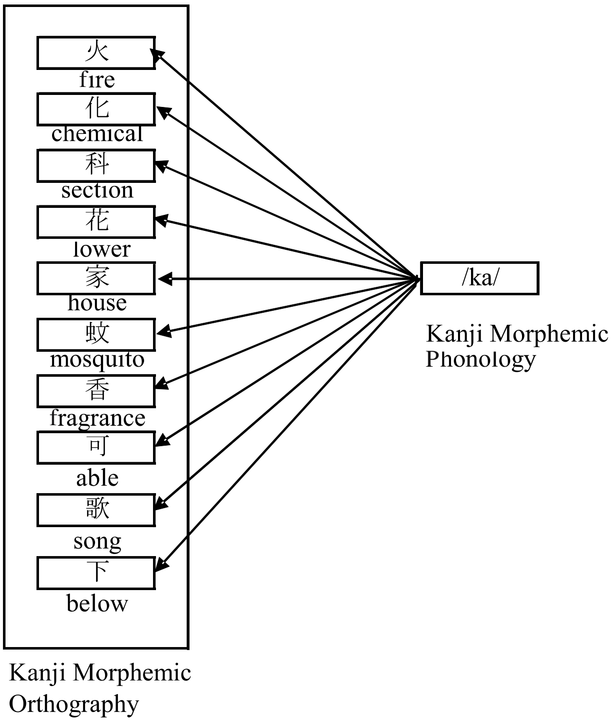

Figure 2. Mapping of a single sound to multiple kanji.

compound words are processed orthographically as a word unit to access their semantic information and that no phonological reference is involved. However, other previous studies (e.g., studies on English by Andrews, 1986; a study on French by Beauvillain 1994, Butterworth, 1983; studies on Japanese by Hirose, 1992; studies on the Chinese language by Perfetti & Zhang, 1991, 1995; Perfetti, Zhang & Berent, 1992; Stanners, Neiser, Hernon & Hall, 1979; Taft, 1991, Tamaoka & Hatsuzuka, 1995, 1998; Tamaoka & Takahashi, 1999; Zhang & Peng, 1992; Zhang & Perfetti, 1993) suggest that morphemic units of compound words were simultaneously activated while processing their lexical units. If these experimental findings are true, the density of morphemic homophony among Japanese kanji as depicted in Figure 2 would affect lexical decision and possibly the naming of two-kanji compound words.

One of examples in daily life often observed is a scene that native Japanese speakers ask which kanji was used for /keN/ as a part of the popular Japanese male name /keN zi/ as having 29 different kanji being the same sound /keN/. As observed in this behavior, higher errors were found in kanji writing by mature native Japanese speakers (Hatta, Kawakami &

Tamaoka, 1998, 2002). Needless to say, presenting a single syllable such as /keN/, /koR/ and /sjoR/ does not reach a single kanji as seen in Figure 2. A kanji is identified only if it is presented as a part of a word. Two kanji are identified only when shown as a part of the word 健康 pronounced /keN koR/ as having 29 kanji for /keN/ and 64 kanji for /koR/ among the commonly-used 1945 basic kanji. Although this mapping characterizes a feature of single kanji, it is hypothesized that multiple kanji morphemes would be automatically activated by a single kanji sound even though a specific target kanji is embedded in a two-kanji compound word. The present study focused on effects of kanji morphemic homophony illustrated in Figure 2 of the mapping of a single kanji sound to multiple kanji during the processing of two-kanji compound words.

Experiment 1: Effects of morphemic homophony on lexical decision

Experiment 1 examined the effects of morphemic homophony on the lexical decision task for two-kanji compound words by altering the homophonic density of both the left-hand and the right-hand position.

Method

Subjects. Twenty-three graduate and undergraduate students who were native speakers of the Japanese language (12 female and 11 male) participated in the experiment. Their ages ranged from 19 to 25; on the day of testing, the average age was 21 years and 4 months for females and 22 years and 5 months for males.

Stimulus items. All kanji characters used for the experiment were selected from the 1945 basic characters taught from the first to ninth grade, in order to assure that all the subjects would be acquainted with them. The extent of kanji homophony was identified by the number of characters which shared the same pronunciation. All possible pronunciations of the 1945 characters were examined to determine the density of morphemic homophony using the database (Tamaoka et al., 2002). In the present study, a high density of homophony refers to sounds represented by more than 20 of the 1945 basic characters, consisting of only 29 such sounds. Sounds represented by less than 7 kanji characters were defined as having a low density of homophony. In this study, ‘sound’ refers to either a single mora (counting the three special sounds as a single mora) or single syllable (including special sounds as a part of a single syllable).

To separately examine the effect of kanji morphemic homophony in the left-hand and right-hand position of two-kanji compound words, four categories of compound words, with 18 words in each category were created: (1) compound words with a high density of homophony in both the left and right kanji (HH condition), (2) words with a low density of homophony in both the left and right kanji (LL condition), (3) words with a high density in the left kanji and a low density in the right (HL condition), and (4) words with a low density in the left and a high density in the right (LH condition). Examples of these four types and their averages of morphemic homophones are shown in Table 1. In this design, two factors (the density of kanji morphemic homophony and the left/right-hand position) can be examined together. The compound words selected were not homophonic with other higher frequency words at the word level. All compound words used in this experiment are listed in the Appendix. One-way ANOVAs indicated that the four conditions of two-kanji compound words showed significant main effects on morphemic homophony in the left-hand position [$F(3, 68) = 62.27$, $P < 0.001$], right-hand position [$F(3, 68) = 72.20$, $P < 0.001$] and both sides together [$F(3, 68) = 24.52$, $P < 0.001$]. Thus, these results served the purpose of the experiment, which was to investigate the effects of kanji morphemic homophony.

The other possible 11 factors (characteristics 2–12), which could affect the processing of kanji compound words, were controlled as shown in Table 1. In the case of word frequency, all four stimulus conditions had exactly the same average of 25.44 occurrences in the total of 1,967,575 printed words, calculated according to an index provided by the National Institute for Japanese Language (1973). Abstractness/concreteness of the stimulus items was measured by a 7-point continuum scale as explained in stimulus items of Experiment 1. Number of morae, radical frequency, number of constituents, On-reading ratio, kanji frequency of both the indexes of 1976 and 1998, neighborhood size, and accumulative neighborhood size were all controlled so as not to have any main effects (see detailed explanations, Tamaoka et al., 2002). Detailed figures for these characteristics across the four stimulus conditions are shown in Table 1. The figures of kanji characteristics from 5 to 12 were taken from Tamaoka et al. (2002). ANOVAs indicated that variables 2–12 (listed in Table 1) did not show significant main effects across the four stimulus conditions of two-kanji compound words together, kanji in the left-hand position and kanji in the right-hand position.

For correct 'no' responses in the lexical decision task, 72 nonwords were created by simply combining two kanji from the list of the 1945 basic Japanese kanji such as 与百, 楽費, 理現 and 郎直.

Table 1. Examples and characteristics of two-kanji compound words for experiments 3 and 4.

	Example of a word	強＋制	気＋温	旅＋館	録＋音	One-way
	Kanji homophonic density of the examples	(30) (34)	(35) (5)	(3) (45)	(3)＋(5)	ANOVA Sig.
		Left- and right-hand positions of two-kanji compound words				
	Characteristics of word stimuli	High + High	High + Low	Low + Low	Low + High	
1	Total of both sides of kanji homophonic density	27.94	15.25	18.22	3.50	**
	Kanji on the Left-hand position	27.56	26.56	3.06	2.89	**
	Kanji on the right hand position	28.33	3.94	33.39	4.11	**
2	Word frequency(1973)	25.44	25.44	25.44	25.44	*n.s.*
3	Abstract-to-concrete scale	4.79	4.73	4.61	4.97	*n.s.*
4	Number of morae	3.400	3.55	3.40	3.70	*n.s.*
5	Total of both sides of radical frequency	62.28	75.39	42.77	54.55	*n.s.*
	Kanji on the left-hand position	26.61	40.5	20.33	24.44	*n.s.*
	Kanji on the right-hand position	35.670	34.89	22.44	30.11	*n.s.*
6	Total of both sides of number constituent	4.39	4.22	4.11	3.89	*n.s.*
	Kanji on the left-hand position	2.28	2.11	1.94	1.83	*n.s.*
	Kanji on the right-hand position	2.11	2.11	2.17	2.06	*n.s.*
7	Average of both sides of On-reading ratio	80.09%	85.86%	81.92%	90.97%	*n.s.*
	Kanji on the left-hand position	76.56%	82.06%	79.61%	90.56%	*n.s.*
	Kanji on the right-hand position	83.62%	89.66%	84.22%	91.37%	*n.s.*
8	Total of both sides of kanji stroke numbers	18.89	18.33	19.06	19.89	*n.s.*
	Kanji on the left-hand position	9.00	9.77	9.67	10.39	*n.s.*
	Kanji on the right-hand position	9.89	8.56	9.39	9.50	*n.s.*

Table 1. Continued.

	Example of a word	強＋制	気＋温	旅＋館	録＋音	One-way
	Kanji homophonic density of the examples	(30) (34)	(35) (5)	(3) (45)	(3)＋(5)	ANOVA Sig.
		Left- and right-hand positions of two-kanji compound words				
	Characteristics of word stimuli	High + High	High + Low	Low + Low	Low + High	
9	Total of both sides of kanji frequency (1976)	0.52	0.44	0.57	0.56	*n.s.*
	Kanji on the left-hand position	0.38	0.28	0.15	0.31	*n.s.*
	Kanji on the right-hand position	0.14	0.17	0.42	0.25	*n.s.*
10	Total of both sides of kanji frequency (1998)	69208	74857	59268	62308	*n.s.*
	Kanji on the left-hand position	36419	34312	21272	30520	*n.s.*
	Kanji on the right-hand position	32789	40545	37996	31788	*n.s.*
11	Total of both sides of neighborhood size	201.49	226.50	256.39	254.11	*n.s.*
	Kanji on the Left-hand position	105.55	118.89	123.28	123.39	*n.s.*
	Left-side to create compound words	59.83	54.89	67.06	63.67	*n.s.*
	Right-side to create compound words	45.72	64.00	56.22	59.72	*n.s.*
	Kanji on the right-hand position	95.94	107.61	133.11	130.72	*n.s.*
	Left-side to create compound words	38.61	43.17	49.17	47.78	*n.s.*
	Right-side to create compound words	57.33	64.44	83.94	82.94	*n.s.*
12	Total of both sides of accumulative neighburhood size	707.67	1087.11	1100.72	912.22	*n.s.*
	Kanji on the Left-hand position	373.22	529.39	364.39	378.22	*n.s.*
	Left-side to create compound words	155.83	173.06	121.39	112.78	*n.s.*
	Right-side to create compound words	217.39	356.33	243.00	265.44	*n.s.*
	Kanji on the right-hand position	334.45	557.72	736.33	534.00	*n.s.*

Table 1. Continued.

Example of a word Kanji homophonic density of the examples	強＋制 (30) (34)	気＋温 (35) (5)	旅＋館 (3) (45)	録＋音 (3)＋(5)	One-way ANOVA Sig.
	Left- and right-hand positions of two-kanji compound words				
Characteristics of word stimuli	High + High	High + Low	Low + Low	Low + High	
Left-side to create compound words	139.39	223.72	276.72	193.11	*n.s.*
Right-side to create compound words	195.06	334.00	459.61	340.89	*n.s.*

Note: $**p < 0.01$.

These nonwords exist neither orthographically nor phonologically in the Japanese language, so that they elicit neutral 'No' responses without specific efforts on the part of the test subjects.

Procedure. Compound words and nonwords were randomly presented to subjects in the center of a computer screen (Toshiba, J-3100 Plasma display) 600 ms after the appearance of an eye fixation point marked by '*'. Stimulus randomization was operated in each subject, so that each subject received a different order of stimulus presentation. The subjects were instructed to respond both as quickly and as accurately as possible in deciding whether the item was a word or not. The response was made by pressing a 'Yes' or a 'No' response key. For instance, after the eye fixation of '*', stimulus item of 体操 is presented, the subject should decide whether this word is real or not as quickly and accurately as possible. In this case, the subject must press the 'Yes' response key for the correct answer. After the response, the subject presses the space key to initiate the next presentation. After 600 ms, the eye fixation point '*' appears for 600 ms. A total of 1200 ms after initiation of the next presentation, a new stimulus word appeared in the position of the eye fixation point. The subject repeated this process until all the words and nonwords were presented. Each response time (i.e., reaction time) and its response result of correct or incorrect (i.e., error rate in the total responses) were recorded by the computer. Sixteen practice trials were given to the subjects prior to the commencement of the actual testing.

Results

The mean reaction times and error rates of high/low kanji morphemic homophony in the left- and right-hand position of the two-kanji compound words are presented in Table 2. Reaction times slower than 2000 ms or faster than 200 ms were recorded as incorrect items. Three responses for real words (correct 'Yes' responses) fell into this category. Only items which were responded to correctly were used for an analysis of reaction times. Before performing the analysis, reaction times outside of 2.5 standard deviations in both the high and low ranges among correct 'Yes' responses were replaced by the boundaries indicated by 2.5 standard deviations from the individual means of subjects in each category. The total of 52 items (3.14%) out of 1656 'Yes' responses (72 items $\times$ 23 subjects) were edited in this standard procedure. The statistical tests which follow analyze both subject ($F1$) and item ($F2$) variability.

Table 2. Means of reaction times and error rates for lexical decision of two-kanji compound real words.

Density of kanji morphemic homophony		Reaction time (ms)		Error rate (%)
Left-hand position	Right-hand position	M	SD	M
High density	High density	762	111	9.90
High density	Low density	738	95	8.70
Low density	High density	705	94	5.07
Low density	Low density	725	89	6.28

A 2 (left-hand and right-hand position) × 2 (high and low homophonic density) ANOVA was carried out for reaction times required to perform the lexical decision task for real words. The interaction between position and density was significant in subject analysis [$F1(1,22) = 13.05$, $P < 0.01$] but not in item analysis [$F2(1,17) = 1.66$, $P = 0.21$]. Further analysis was carried out to separately examine the effect of kanji homophonic density in the left-hand and right-hand position of two-morpheme compound words. Analysis revealed that the reaction times differed significantly according to the density of morphemic homophony (High = 750 vs. Low = 715 ms) in the left-hand kanji [$F1(1,22) = 18.10$, $P < 0.001$; $F2(1,17) = 6.92$, $P < 0.05$] while no difference in reaction time was found when the morphemic homophony of the right-hand kanji (High = 734 vs. Low = 732 ms) was altered [$F1(1,22) = 0.06$, $P = 0.80$); $F2(1,17) = 0.24$, $P = 0.63$]. This result indicated that the density of kanji homophony in the left-hand position affected lexical decision for compound words whereas the density of kanji homophony in the right-hand position did not.

Likewise, the error ratios differed according to the density of morphemic homophony in the left-hand kanji [$F1(1,22) = 8.89$, $P < 0.01$; $F2(1,17) = 6.39$, $P < 0.05$], but not in the right-hand kanji [$F1(1,22) = 0.00$, $P < 1.00$; $F1(1,17) = 0.00$, $P = 0.95$]. The interaction between position and density was not significant [$F1(1,22) = 1.85$, $P = 0.19$; $F2(1,17) = 0.17$, $P = 0.68$]. Thus, similar effects were found for both error ratios and reaction times.

Discussion

The density of kanji morphemic homophony was observed only in subject analysis, but not in item analysis. Thus, density of morphemic homophony had no clearly evident effect on lexical decision for whole words. However, the effects of morphemic homophonic density were observed with kanji in the left-hand position, but not in the right-hand position, which was confirmed by significance in both subject and item analysis. One can explain this tendency by suggesting that the kanji situated in the left-hand position of a two-morpheme compound word not only automatically activates its correct (in this compound) pronunciation but also exhaustively activates various other orthographic representations of its kanji morphemic homophony, regardless of whether this has any practical or strategic value. A high density of kanji homophony in the right-hand kanji could very well affect lexical decision, but assuming that compound words are processed from left-to-right as visually presented, this effect was not apparent as lexical decision was made before the effect of right-hand kanji homophony arose. Experiment 2 was conducted to examine the same effects of morphemic homophony on the separate task of naming these words.

Experiment 2: Effects of morphemic homophony on naming

Experiment 1 demonstrated the effects of morphemic homophony on lexical decision regarding two-kanji compound words even though the task did not necessarily require phonological activation at the morpheme level. In contrast, for the naming of two-kanji compound words, the response is based on phonology. Therefore, phonological representations of kanji, or at least words, must be activated in order to pronounce them. Thus, the present study expected to find an inhibitory effect of kanji homophonic density on naming two-kanji compound words. However, since subjects were required only to name a word in the naming task, it was also hypothesized that there would be no need of kanji orthographic activation from a target kanji sound to perform the naming task. Experiment 2, therefore, investigated the effects related to the density of morphemic homophony using the naming task of two-kanji compound words. Nonwords used in Experiment 1 were not included in Experiment 2.

Method

Subjects. Twenty-four graduate and undergraduate students who were native speakers of the Japanese language (12 female and 12 male) participated in the experiment. Their ages ranged from 19 to 31; on the day of testing, the average age was 22 years and 6 months for females and 23 years and 6 months for males. Those who were tested in Experiments 1 were not included in Experiment 2.

Materials. The 72 compound real words used in Experiment 1 were also used in Experiment 2 for the naming task. Since the nonwords with two kanji combinations in Experiment 2 were not pronounceable due to the multiple kanji readings, nonwords were not included in Experiment 2.

Procedure. Compound word items were randomly presented (each subject receive a different randomization) to subjects in the center of the computer screen 600 ms after the appearance of an eye fixation point marked by '*'. The subjects were required to pronounce the compound word shown on the screen as quickly but as accurately as they could. A voice-key turned off the timer to measure the naming latency. The correctness of pronunciation was entered into the computer by the examiner. The next fixation point was presented 600 ms after the examiner pressed a key. Twelve practice trials were given to the subjects prior to commencement of the actual testing.

Results

The mean latency times and error rates of high/low density of kanji homophony in the left-hand and right-hand kanji of the compound words are presented in Table 3. Naming latencies longer than 2000 ms or shorter than 200 ms were recorded as incorrect items. No responses fell into this category. Only correctly pronounced items were used for an analysis of naming latencies. Before performing the analysis, naming latencies outside of 2.5 standard deviations in both the high and low ranges were replaced by the boundaries indicated by 2.5 standard deviations from the individual means of subjects in each category. The total of 48 items (2.70%) out of 1776 'Yes' responses (72 items × 24 subjects) were edited in this standard procedure. The statistical tests follow the convention of analyzing both subject ($F1$) and item ($F2$) variability.

Table 3. Means of naming latencies and error rates for lexical decision of two-kanji compound real words.

Density of kanji morphemic homophony		Naming latency (ms)		Error rate (%)
Left-hand position	Right-hand position	M	SD	M
High density	High density	608	95	1.16
High density	Low density	599	89	1.85
Low density	High density	576	96	0.69
Low density	Low density	596	115	1.16

As with Experiment 1, a 2 (left-hand and right-hand position) × 2 (high and low kanji homophonic density) ANOVA was carried out for naming latencies required to perform the naming task. The interaction between the density of morphemic homophony and the position was significant in subject analysis [$F1(1,23) = 7.59$, $P < 0.01$] but not in item analysis [$F2(1,17) = 1.66$, $P = 0.21$]. Further analysis was carried out to separately examine the effect of kanji homophony in the left-hand and right-hand positions. The naming latency differed significantly according to the density of morphemic homophony in the left-hand kanji (High = 604 vs. Low = 588 ms) [$F1(1,23) = 8.16$, $P < 0.01$; $F2(1,17) = 4.77$, $P < 0.05$] while no difference was observed when the density of morphemic homophony was altered in the right-hand kanji (High = 592 vs. Low = 598 ms) [$F1(1,23 = 1.53$, $P = 0.22)$; $F2(1,17) = 0.10$, $P = 0.75$]. Thus, as the results of the lexical decision task in Experiment 1 illustrated, naming was also affected by the density of kanji morphemic homophony in the left-hand kanji of the two-kanji compound words.

In the analysis of the error ratios, neither the subject analysis nor the item analysis was significant. Error ratios did not differ with the density of homophony in the left-hand kanji [$F1(1,23) = 2.00$, $P = 0.17$; $F2(1,17) = 1.20$, $P = 0.28$] nor in the right-hand kanji [$F1(1,23) = 1.00$, $P = 32$; $F2(1,17) = 0.60$, $P = 0.45$]. The interaction was not significant [$F1(1,23) = 0.06$, $P = 81$; $F2(1,17) = 2.25$, $P = 0.15$]. Consequently, there was no effect of morphemic homophony on naming errors.

Discussion

As was the case in the lexical decision task of Experiment 1, the performance of the naming task was affected by the density of morphemic homophony only in the left-hand position. This confirms the explanation given for the results of Experiment 1 being that kanji situated in the left-hand position of two-kanji compound words activate kanji phonology, which further activate additional orthographic representations of their homophones at the morpheme level.

General discussion

Previous studies on kanji sounds were mostly focused on the mapping of a single kanji to multiple sounds (see Figure 1) in either a single kanji (Kayamoto et al., 1998) or a two-kanji compound word (Wydell et al., 1995). However, much heavier density of kanji homophones is observed in the opposite direction of the mapping of a single sound to multiple kanji morphemes (see Figure 2). Thus, the present study investigated exhaustive activations from phonology to orthography created at the kanji morphemic level during the processing of two-kanji compound words.

A high degree of morphemic homophony was defined as kanji having more than twenty commonly-used kanji homophones. A visually-presented word generates an activation of an orthographic representation which further activates its phonological representation. In turn, the phonological representation reverberates back to generate a series of orthographic representations of kanji morphemic homophones. The present study made an assumption that these simultaneously activated orthographic representations at the morphemic level must be suppressed, therefore inhibiting the speed of task performance.

Experiments 1 and 2 investigated homophonic effects at the morphemic level by controlling lexical homophony. Although the results were not clear across the four conditions of homophonic density for two-kanji compound words (i.e., two kanji combination of high/high, high/low, low/high and low/low homophonic density), the generally observable effects of morphemic homophony are that kanji morphemic homophony in the left-hand position seemed to affect reaction times for lexical decision and latencies for naming of two-kanji compound words. This effect was not seen at all in the right-hand position.

Although various homophonic kanji which share the same sound with the right-hand kanji could be automatically activated during the processing of the compound word, the effects of kanji homophony were observed only in the left-hand position. The following explanation is given for the results of the present experiments. If the processing of a two-morpheme compound word proceeds from left to right, activation of the morphemic unit presented on the left will commence before activation of the right-hand unit. A whole-word orthographic representation for lexical decision will then be activated to complete the task at hand before the activations of kanji homophony from a kanji sound in the right-hand kanji can start to affect the processing of the compound word. Therefore, based upon the results of Experiments 1, the present study suggests that kanji orthographic activations from single kanji phonology occur at the morphemic level. This exhaustive activation of multiple kanji orthography from a single kanji sound results in slower processing for words with a high density of morphemic homophony, which is observed as an inhibitory effect in the performance of the lexical decision task.

In Experiment 2, the morphemic homophonic effect on naming was investigated, using stimuli of two-kanji compound words. It is assumed that once the phonological representation of a target word like /sai koR/ is activated, it should be sufficient to perform the naming task since the task only requires vocalization of the target word. Thus, it is expected that no difference in naming latencies would be observed between the high and low degree of morphemic homophony. Notwithstanding this expectation, an inhibitory effect of morphemic homophony was observed in the naming performance in Experiment 2. Therefore, homophonic effects on naming at the morphemic level indicated a very similar trend to that of the lexical decision task, suggesting that the naming of a two-kanji compound word slowed when a kanji with a high degree of kanji homophony (i.e., having more than 20 kanji homophones) appears in the left-hand position. A single kanji presented as part of a two-kanji compound word cannot provide enough information for subjects to select the proper pronunciation from among its multiple kanji pronunciations. Subjects would first reference the second kanji as a combination partner. The kanji phonology in the left-hand position (i.e., /sai/) will be automatically activated soon after an activation of the lexical phonology of the two-kanji compound word. However, in the naming task, before kanji homophony in the right-hand position creates activations of kanji orthographic representations from a kanji sound, the lexical level of phonology (i.e., /sai koR/) will come to function. Thus, kanji homophony in the right-hand position will not cause significant interference on the naming of two-kanji compound words.

Related to kanji homophony in the present study, Hatta et al. (1998, 2002) provided some interesting data regarding kanji writing errors. Of the types of errors that native Japanese speakers make, phonologically related kanji writing errors were the most numerous (60.0%), followed by orthographically related errors (43.6%) and semantically related errors (29.7%). The above percentages total more than 100% because a degree of overlapping of these three types was also observed. Many of the phonological errors were found among kanji homophony: instead of writing the correct kanji, subjects typically replaced it with one which was incorrect but which commonly shared the same On-reading. Thus, it is necessary to properly inhibit orthographic representations of unrelated homophonic kanji, especially when the kanji to be written is one with a high density of homophony. The research findings of Hatta et al. (1998, 2002) in the kanji writing task also supports the assertion that various orthographic representations of homophonic kanji are activated via the shared single kanji sound even though processing two-kanji compound words.

Notes

1. The pronunciation of Japanese words in this paper is transcribed using Japanese phonemic symbols which indicate three special sounds in Japanese: /N/ for nasal, /Q/ for geminate and /R/ for long vowel.
2. In this paper, an alphabetic description of Japanese names follows the commonly used Hepburn style. Thus, the spelling of 'Saito' is used, even though this name is pronounced /saitoR/ with a long vowel. However, as the Hepburn style does not distinguish between long and short vowels, Japanese titles of research papers which include long vowels are shown by repeating the same vowels twice, such as 'oo'.

Appendix

Stimuli Used in Experiments 1 and 2

1. Two kanji combinations with high/high degree of kanji homophony

体操 /tai soR/	要請 /joR seR/	進呈 /siN teR/	身長 /siN tjoR/
周囲 /suR i/	寄付 /ki hu/	相違 /soR i/	研修 /keN suR/
統計 /toR keR/	会期 /kai ki/	移行 /i koR/	抱負 /hoR hu/
強制 /kjoR seR/	庭球 /teR kjuR/	青果 /seR ka/	急進 /kjuR siN/
公費 /koR hi/	軽視 /keR si/		

2. Two kanji combinations with high/low degree of kanji homophony

気温 /ki oN/	改善 /kai zeN/	意欲 /i joku/	休日 /kjuR zitu/
当分 /toR buN/	観客 /kaN kjaku/	選抜 /seN batu/	採決 /sai ketu/
対局 /tai kjoku/	海域 /kai iki/	郷土 /kjoR do/	景品 /keR hiN/
持続 /zi zoku/	法務 /hoR mu/	様式 /joR siki/	調達 /tjoR tatu/
亡命 /boR meR/	考案 /koR aN/		

3. Two kanji combinations with low/high degree of kanji homophony

旅館 /rjo kaN/	明記 /meR ki/	出身 /sjuQ siN/	劇場 /geki zjoR/
愛情 /ai zjoR/	画家 /ga ka/	育成 /iku seR/	悪化 /aQ ka/
風景 /huR keR/	母校 /bo koR/	必死 /hiQ si/	達成 /taQ seR/
絶望 /zetu boR/	屈指 /kuQ si/	空間 /kuR kaN/	類型 /rui keR/
乱用 /raN joR/	鈍感 /doN kaN/		

4. Two kanji combinations with low/low degree of kanji homophony

連絡 /reN raku/	台所 /dai dokoro/	圧力 /atu rjoku/	録音 /roku oN/
運命 /uN meR/	論文 /roN buN/	血液 /ketu eki/	秩序 /titu zjo/
税率 /zeR ritu/	難問 /naN moN/	歴任 /reki niN/	発育 /hatu iku/
内野 /nai ja/	直結 /tjoQ ketu/	魚類 /gjo rui/	保安 /ho aN/
学業 /gaku gjoR/	黙認 /moku niN/		

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