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Phonological and semantic activation in reading two-kanji compound words

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ABSTRACT
The purpose of this study was to examine whether phonological information was activated automatically in processing two-kanji compound words. In Experiment 1, 27 participants judged whether pairs of the words were homophones, while another 27 participants judged whether pairs were synonyms. Stimulus onset asynchrony (SOA) was 140 ms, 230 ms, or 320 ms. In Experiment 2, 36 participants were asked to make one of the two judgments, as in Experiment 1. SOA was determined individually. The following results were found. Reaction times showed semantic interference. Phonological interference was observed only under the shortest SOA in Experiment 2. Error rates showed phonological and semantic interferences even when SOA was the longest. These findings support the universal phonological principle.

Skilled readers usually read words or sentences to comprehend their meaning. How is phonological information processed in reading? In hearing speech, we must process the phonological information before anything else in order to comprehend it. Is phonology necessarily processed in reading?

Theories about the role of phonology in reading seem to fall roughly into three groups. First, some investigators have adopted the universal direct access hypothesis, whereby phonological information is not supposed to be necessary in reading (e.g., Develaar, Coltheart, Besner, & Jonasson, 1978; Paap, Newsome, McDonald, & Schvaneveldt, 1982). According to this hypothesis, there are two routes by which the meaning of words may be accessed: the lexical route and the phonologically mediated route. Word recognition is thought to be accomplished directly by the visual route in all writing systems, and phonological activation is considered to be optional (Baluch & Besner, 1991).

Second, other investigators have supported the orthographic depth hypothesis, which presumes that the occurrence of phonological activation depends on orthographic depth (e.g., Feldman & Turvey, 1983; Frost, Katz, & Bentin, 1987). When the grapheme–phoneme mappings are consistent, as in Serbo-Croatian and Italian (shallow orthography), the semantic process is mediated by a phono-

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logical process which changes written strings to phonemic strings. When the grapheme–phoneme mappings are inconsistent, as in English and Hebrew (deep orthography), readers have direct access from orthographic information to semantic information, and phonological information is not required.

Finally, some investigators have insisted that phonological activation always occurs, and that phonological information is activated automatically at the time of access of semantic information. Phonological activation is a part of reading and thus cannot be suppressed (e.g., Ferrand & Grainger, 1992; Lesch & Pollastek, 1993).

Perfetti, Tan, and their colleagues (Perfetti & Zhang, 1995; Tan, Hoosain, & Peng, 1995; Tan, Hoosain, & Siok, 1996) examined the role of phonological information using Chinese characters (called kanji in Japanese). Chinese is considered to be a logography, a system in which the basic unit in writing is associated with a unit of meaning, differing greatly from the alphabetic writing system. Their results showed that phonological information was activated automatically and could not be suppressed even in kanji reading. Based on these results, they advocated the universal phonological principle. According to this principle, encounters with printed words activate multiple levels of phonology in all writing systems. Features of a writing system may control the details of how various phonological levels are activated, but the phonological activation itself is universal (Perfetti & Tan, 1998) and is assumed to be a part of character identification.

On the other hand, in reading Japanese kanji it has generally been claimed that phonological activation is not necessary (Inoue, Saito, & Ishihara, 1979; Kaiho, 1975; Kimura, 1984; Nomura, 1981; Saito, 1981). However, Wydell, Patterson, and Humphreys (1993) found that, in a semantic judgment task using two-kanji compound words, phonological information affected reaction times in semantic judgments. They suggested that this could be taken as evidence for the existence of two routes (through orthography and phonology) to semantic information. However, because they did not examine whether semantic information affected reaction times in phonological judgments, it is reasonable to say that their study did not provide enough evidence to derive a conclusion on this matter.

The present study was designed to clarify the question of whether phonological activation always occurs in reading, using kanji characters in Japanese. Japanese kanji seems to be one of the most suitable writing systems to use in the search of an answer to our first question: that is, whether phonology is necessarily processed even in reading. Japanese kanji are derived from Chinese characters. However, there are several differences in function between Japanese kanji and Chinese characters. Most characters in Chinese are monosyllabic, whereas most Japanese kanji characters have more than two syllables, and many have two or more different pronunciations. For example, the single kanji 人 is pronounced "hito" (meaning 'person'), whereas 人気 is pronounced "ninki" (meaning 'popularity') and 人口 is pronounced "jinkou" (meaning 'population'). Thus, 人 has three different pronunciations in Japanese ("hito," "nin," and "jin"), whereas in Chinese, it has only one pronunciation ("zen"). Therefore, when reading aloud, Japanese readers must decide which pronunciation is proper for each

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kanji, taking into consideration the combination of kanji characters, the context, or both. Furthermore, Japanese uses another kind of writing system – kana. Each kana character usually has no meaning, but contains phonetic information; a certain string of kana characters has meaning just like alphabet characters. In general, any given sentence includes both kanji and kana. These differences between Japanese and Chinese seem to imply that Japanese kanji contain more complex phonological information and are more specialized in offering meaning than Chinese characters.

If it can be shown that the phonological activation occurs automatically in Japanese kanji, this will lend support to the universal phonological principle. If not, this will lend support to the universal direct hypothesis or the orthographic depth hypothesis.

In the present experiments, a method similar to that of Perfetti and Zhang (1995) was used. However, Perfetti and Zhang used single Chinese characters; in the present study Japanese two-kanji compound words were used. This is because most Japanese single-kanji characters have two or three different pronunciations, whereas most two-kanji compound words have only one. Following Perfetti and Zhang, the present study manipulated the length of the stimulus onset asynchrony (SOA) as an experimental variable to determine the time course of the phonological activation and semantic activation. SOA, which is the interval from the onset of the first stimulus to that of the second one, is used when a participant is required to judge whether the two stimuli are the same with regard to pronunciation or meaning.

EXPERIMENT 1

Method

Participants. A total of 54 Japanese undergraduate students (34 females, 20 males) participated in the experiment. Their ages ranged from 20 to 23 years old.

Materials. The materials consisted of 324 two-kanji compound words, 81 of which were used as core words. Each core had three types of cohort: a homophone of the core, a synonym of the core, and one unrelated to the core. Therefore, there were 81 homophone pairs, 81 synonym pairs, and 81 control pairs. Table 1 shows an example of three kinds of pairs with a common core (see also the Appendix). The homophones, synonyms, and unrelated words were also two-kanji compound words, so that the total of the two-kanji compound words used in this experiment was 324.

To prepare these materials, two questionnaires were carried out. The aim of the first one was to select pairs of words that students would recognize as homophones or synonyms. The aim of the second one was to select three types of cohorts that would be similar to each other in familiarity.

To prepare the questionnaires, candidates for the materials were selected from a synonym dictionary (Takebe, 1995). There were three requirements for the selection of candidates for the core: (a) each had to be a two-kanji compound

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Table 1. *Example of materials*

	Pronunciation	Meaning
Homophone pair		
感嘆		
	/ kantan /	'admiration'
簡単	/ kantan /	'easy'
Synonym pair		
平易		
	/ heii /	'easy'
簡単	/ kantan /	'easy'
Control pair		
芝居		
	/ shibai /	'drama'
簡単	/ kantan /	'easy'

Note: 簡単 is the core word.

word; (b) each had to have a homophone that was also a two-kanji compound word; and (c) each had to have a synonym that was also a two-kanji compound word. We selected 104 candidates for the core words, each of which had both homophones and synonyms. This means that 104 candidates of homophone pairs, 104 candidates of synonym pairs, and 104 candidates of control pairs were prepared in which the core words were common among the three types of pairs.

In the first questionnaire, 40 undergraduate students rated the 312 pairs on a 5-point similarity scale. Half were asked to rate the phonological similarity of each pair; the other half were asked to rate the semantic similarity. In the second questionnaire, 18 different undergraduate students rated the 312 pairs on a 5-point familiarity scale.

Eighty-one homophone pairs whose mean rating scores in phonological similarity were high and whose mean rating scores in semantic similarity were as low as those of the control pairs were selected. Eighty-one synonym pairs whose mean rating scores in semantic similarity were high and whose mean rating scores in phonological similarity were as low as those of the control pairs were selected. The mean rating scores of familiarity for the three types of cohorts had to be as close as possible (see the Appendix). Six homophone pairs, six synonym pairs, and six control pairs were selected from the remainder for use during the training trials.

Tasks. There were two kinds of tasks: the homophone judgment task and the synonym judgment task. Half the participants took part in the homophone judgment task, and the other half took part in the synonym judgment task.

The same 243 pairs were used in both the homophone judgment task and the synonym judgment task. Each participant was presented with 81 pairs of words from the 243 pairs: 27 homophone pairs, 27 synonym pairs, and 27 control pairs. The 81 core words were the same for all participants, but the types of

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cohorts paired with these core words were changed among the participants so that every pair was used the same number of times in the experiment.

Participants in the homophone judgment task were told to press one of two buttons according to whether the pronunciation of two two-kanji compound words presented successively was the same or different in each trial. Participants were instructed to focus on the pronunciation of the two-kanji compound words and to respond as quickly and precisely as possible. They were instructed to press a button even if they could not judge clearly and to ignore differences in accent between the two words. The experimenter stressed that the meanings of the two words did not relate to the task at all.

Participants in the synonym judgment task were asked to press one of two buttons according to whether the meanings of two two-kanji compound words presented successively were similar or not in each trial. The experimenter stressed that participants should pay attention only to meaning, and that pronunciations of the two words did not relate to the task at all.

Stimulus onset asynchrony. For both tasks, in each trial a cohort was presented and then its core was presented. The core word remained until the participant responded. The interstimulus interval between the offset of the cohort and the onset of its core was 10 ms in all trials. Therefore, SOA (the interval from the onset of the cohort to the onset of its core) was the same as the duration of presentation of the cohort word plus 10 ms. There were three values of SOA: 140 ms, 230 ms, and 320 ms.

For each participant, 27 pairs of each of the three types of pairs were divided into three groups of nine pairs. These were then used, one by one, under the three conditions of SOA. Each pair was presented at the same rate under the three conditions of SOA.

The three values of SOA were determined from the results of a preliminary test in which another group of participants (12 graduate and undergraduate students) took part. The shortest SOA, 140 ms, was the interval at which almost all participants were able to make judgments in both tasks, although a few said it was difficult to respond. The longest SOA, 320 ms, was long enough for almost 100% correct judgments to be made by every participant.

Apparatus. Each two-kanji compound word was presented by a tachistoscope (Iwatsu ISEL IS-720). The size of the display was 25 cm $\times$ 40 cm, and the stimuli were presented in an area of 2.3 cm $\times$ 4.6 cm. The viewing distance was 90 cm. The tachistoscope was connected to a personal computer (Fujitsu FMV-DESKPOWER SE/SP) to control the presentation of the stimuli and to record reaction times and errors. The electric buttons, connected to the computer, were put on a desk in front of the participant. One was labeled "same" and the other "different." The experiment was carried out individually in a dark room.

Procedure. In each task, all 81 trials were divided into three blocks of 27 trials, each of which was carried out under one of the three conditions of SOA. For half the participants, the order of the three blocks was 140 ms, 230 ms, and 320 ms. For the other half, the order was reversed. Each block included 6 training

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Table 2. *Mean reaction times in ms* (SD) *of correct responses under each SOA in the homophone judgment task* (*Experiment 1*)

	SOA		
Cohort	140 ms	230 ms	320 ms
Homophone	588 (85)	546 (74)	519 (52)
Synonym	644 (101)	553 (67)	550 (58)
Control	574 (81)	526 (76)	526 (53)

Note: In the homophone pairs, "same" was the correct response, whereas in the synonym and control pairs, "different" was the correct response.

trials and 27 experimental trials. In the training trials, two homophone pairs, two synonym pairs, and two control pairs were presented in a random order. In the experimental trials, nine homophone pairs, nine synonym pairs, and nine control pairs were presented in a random order for each participant. At the beginning and the end of both the training trials and the experimental trials, an asterisk was presented in the middle of the display as a fixation point or sign of the end of the experiment. After the task, participants were asked to describe anything that they had felt or had been conscious of during the experiment.

Results

For each participant, the results of trials whose reaction times were 2.5 standard deviations or more away from her or his mean under each condition were excluded from the following analyses (about 1% of the reaction times were excluded).

Homophone judgment task. At first, the mean reaction times and mean error rates of nine homophone pairs, nine synonym pairs, and nine control pairs under each condition of SOA were calculated for each participant. Then, the means of the mean reaction times (Table 2) and the means of the mean error rates (Table 3) were calculated for the three kinds of pairs. In the homophone judgment task, a comparison of the results of the synonym pairs with those of the control pairs is emphasized, though the results of the homophone pairs are also shown in the tables. An ANOVA of Pair Type (synonym vs. control) × SOA (140 ms, 230 ms, and 320 ms) applied to reaction times indicated that the two main effects and their interaction were significant, $F(1\ 26) = 59.66$, $p < .001$; $F(2, 52 = 18.60$, $p < .001$; $F(2, 52) = 8.91$, $p < .001$, respectively. The results of the simple main effect and multiple comparison tests (Ryan's procedure) at the .05 level of significance were as follows. Under every condition of SOA, the mean reaction time for the synonym pairs was significantly longer than that for the control pairs; the difference was the largest under the condition of 140 ms. The mean

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Table 3. *Mean percentages of error* (SD) *under each SOA in the homophone judgment task* (*Experiment 1*)

	SOA		
Cohort	140 ms	230 ms	320 ms
Homophone	14.4 (8.8)	9.5 (8.7)	8.2 (6.6)
Synonym	4.9 (7.1)	4.5 (7.1)	3.7 (6.2)
Control	2.1 (4.4)	1.6 (5.1)	0.4 (2.1)

Note: In the homophone pairs, "different" was the error response, whereas in the synonym and control pairs, "same" was the error response.

Table 4. *Mean reaction times in ms* (SD) *of correct responses under each SOA in the synonym judgment task* (*Experiment 1*)

	SOA		
Cohort	140 ms	230 ms	320 ms
Synonym	725 (117)	685 (118)	668 (127)
Homophone	705 (125)	629 (83)	631 (87)
Control	731 (131)	650 (94)	636 (94)

Note: In the synonym pairs, "same" was the correct response, whereas in the homophone and control pairs, "different" was the correct response.

reaction time under the condition of 140 ms was significantly longer than those under the conditions of 230 ms and 320 ms, for both types of pairs; the effect was larger in the synonym pairs than in the control pairs.

The same kind of ANOVA was carried out based on error rates after the angular transformation. Only the main effect of pair type was significant, $F(1, 26) = 16.68$, $p < .001$. Participants made significantly more errors in the synonym pairs than in the control pairs under every SOA.

After the task, 96% of the participants reported that they had been conscious of semantic interference.

Synonym judgment task. In the synonym judgment task, both reaction times of correct responses and error rates were analyzed for the homophone pairs and were compared with those for the control pairs, though the results of the synonym pairs are also presented in Tables 4 and 5. Table 4 shows the mean reaction times of the 27 participants. An ANOVA of Pair Type (homophone vs. control) × SOA (140 ms, 230 ms, and 320 ms) indicated that only the main effect of SOA was significant, $F(2, 52) = 14.22$, $p < .001$. The mean reaction

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Table 5. *Mean percentages of error* (SD) *under each SOA in the synonym judgment task* (*Experiment 1*)

	SOA		
Cohort	140 ms	230 ms	320 ms
Synonym	11.5 (9.4)	7.8 (7.8)	7.8 (7.8)
Homophone	9.1 (12.0)	4.1 (6.3)	4.1 (7.0)
Control	2.9 (7.3)	2.1 (5.4)	2.1 (6.2)

Note: In the synonym pairs, "different" was the error response, whereas in the homophone and control pairs, "same" was the error response.

time under the condition of 140 ms was significantly longer than those under the conditions of 230 ms and 320 ms, including both types of pairs.

The mean error rates are shown in Table 5. An ANOVA indicted that only the main effect of pair type was significant, $F(1, 26) = 16.32$, $p < .001$. The participants made more errors on the homophone pairs than on the control pairs. When we tested the simple main effects, a significant effect was observed only under the condition of 140 ms.

Only 11% of participants reported phonological interference.

Discussion

In the homophone judgment task, both the results of the reaction times and those of the error rates showed semantic interference. The interference was observed under all conditions of SOA, though with respect to the reaction time the interference was the largest under the condition of 140 ms. In the synonym judgment task, phonological interference was observed only in the error rate; it was especially strong under the condition of 140 ms. These findings and the participants' reports do not suggest that semantic access is mediated by phonological information.

The most important question in the present study is whether phonological activation occurs automatically in semantic judgment. If the participant could make the semantic judgment without phonological activation, the participant must have suppressed this activation, especially when SOA was very short. A very short SOA signifies a duration that is long enough to make the semantic judgment but too short to permit the activation of unnecessary information. However, in this experiment, some participants were able to respond easily even under the shortest SOA (140 ms), whereas others recognized words only with great difficulty under this condition. Thus, 140 ms seemed to be a little too long for some participants, appropriate for some, and too short for others. Therefore, before drawing any conclusions it would be necessary to carry out the experi-

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ment again using the shortest SOA for each participant. For this reason, the shortest condition of SOA was individually determined through a thresholding procedure in Experiment 2.

EXPERIMENT 2

Method

Participants. A total of 36 Japanese undergraduate students (30 females, 6 males) participated in the experiment. Their ages ranged from 18 to 23 years. None of them had participated in Experiment 1. Half the participants took part in the homophone judgment task, and the other half took part in the synonym judgment task.

Procedure. To determine the shortest SOA for each participant, all participants took part in a preliminary task. They were asked to read aloud 10 pairs of two-kanji compound words presented successively on the display. The interval between the offset of a word and the onset of the next word was always 10 ms. For the first 10 pairs, SOA began at 150 ms. If the participant could correctly read 8 out of 10 pairs, SOA was reduced by 10 ms in the next trials. SOA was successively reduced by 10 ms if the participant passed this criterion. When the participant could not read more than 2 out of 10 pairs at a certain value of SOA, 10 ms was added to the value in the next 10 trials. If the participant passed the criterion, this value was chosen as the shortest SOA for him or her. This SOA was considered to be the shortest condition for the participant to recognize two-kanji compound words correctly. The value of the middle SOA was set to be 60 ms longer than the shortest SOA, and the value of the longest SOA was set to be 60 ms longer than the middle SOA.

The mean of the shortest SOA was 105 ms ($SD = 34$ ms) in the homophone judgment task and 118 ms ($SD = 19$ ms) in the synonym judgment task.

The procedures after setting the shortest SOA, the tasks, and the materials were the same as those in Experiment 1.

Results

The procedures for analyses were the same as those of Experiment 1.

Homophone judgment task. Table 6 shows the mean reaction times of 18 participants. An ANOVA of Pair Type (synonym vs. control) × SOA (shortest, medium, and longest) indicated that the main effect of SOA and the interaction of pair type and SOA were significant, $F(2, 34) = 4.77$, $p < .001$; $F(2, 34) = 32.71$, $p < .05$, respectively. The results of the simple main effect and multiple comparison tests were as follows. The mean reaction time under the condition of the shortest SOA was significantly longer than those under the conditions of the medium and the longest SOAs for both types of pairs; the effect was larger in the synonym pairs than in the control pairs. Under the condition of the shortest

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Table 6. *Mean reaction times in ms* (SD) *of correct responses under each SOA in the homophone judgment task* (*Experiment 2*)

	SOA		
Cohort	Shortest	Medium	Longest
Homophone	911 (248)	680 (109)	620 (79)
Synonym	1,051 (294)	663 (98)	661 (124)
Control	973 (299)	661 (132)	651 (184)

Note: In the homophone pairs, "same" was the correct response, whereas in the synonym and control pairs, "different" was the correct response.

Table 7. *Mean percentages of error* (SD) *under each SOA in the homophone judgment task* (*Experiment 2*)

	SOA		
Cohort	Shortest	Medium	Longest
Homophone	22.2 (8.7)	14.8 (5.3)	13.3 (3.6)
Synonym	18.5 (14.3)	4.9 (7.8)	4.9 (5.7)
Control	7.4 (5.4)	4.9 (5.7)	3.7 (5.4)

Note: In the homophone pairs, "different" was the error response, whereas in the synonym and control pairs, "same" was the error response.

SOA only, the mean reaction time in the synonym pairs was significantly longer than that in the control pairs.

Table 7 shows the mean error rates. The same kind of ANOVA indicated that the two main effects were significant, $F(1, 17) = 5.47$, $p < .05$; $F(2, 34) = 23.92$, $p < .001$, respectively. With respect to their interaction, there was a tendency toward significance $F(1, 17) = 3.13$, $p < .10$. The results of the simple main effect and multiple comparison tests showed that the mean error rate in the synonym pairs was significantly higher than that in the control pairs under the condition of the shortest SOA, and that the participants made more errors under the condition of the shortest SOA than under the conditions of the medium and the longest SOAs in the synonym pairs.

Synonym judgment task. The mean reaction times are shown in Table 8. An ANOVA of Pair Type (homophone vs. control) × SOA (shortest, medium, and longest) indicated that the main effect of SOA and the interaction of pair type and SOA were significant, $F(2, 34) = 33.57$, $p < .001$; $F(2, 34) = 8.73$, $p < .001$,

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Table 8. *Mean reaction times in ms* (SD) *of correct responses under each SOA in the synonym judgment task* (*Experiment 2*)

	SOA		
Cohort	Shortest	Medium	Longest
Synonym	1,032 (302)	741 (157)	817 (169)
Homophone	1,154 (376)	788 (254)	760 (215)
Control	1,010 (221)	806 (159)	740 (163)

Note: In the synonym pairs, "same" was the correct response, whereas in the homophone and control pairs, "different" was the correct response.

Table 9. *Mean percentages of error* (SD) *under each SOA in the synonym judgment task* (*Experiment 2*)

	SOA		
Cohort	Shortest	Medium	Longest
Synonym	12.9 (8.6)	6.2 (7.1)	13.3 (6.2)
Homophone	9.2 (7.9)	7.4 (7.6)	5.6 (8.7)
Control	5.6 (5.7)	3.7 (5.4)	5.6 (8.7)

Note: In the synonym pairs, "different" was the error response, whereas in the homophone and control pairs, "same" was the error response.

respectively. The results of the simple main effect and multiple comparison tests showed that the reaction times under the condition of the shortest SOA were longer than those under the conditions of the medium and the longest SOAs in both the homophone pairs and the control pairs, and that the mean reaction time in the homophone pairs was significantly longer than that in the control pairs under the condition of the shortest SOA only.

Table 9 shows the mean error rates. An ANOVA indicated that only the main effect of pair type was significant, $F(1, 17) = 4.76$, $p < .05$. The participants made more errors on the homophone pairs than on the control pairs. However, when multiple comparison tests were carried out, the effect was significant only under the conditions of the shortest and the medium SOAs.

Discussion

In the homophone judgment task, the results of reaction times and error rates indicated clear semantic interference only under the condition of the shortest

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SOA. In the synonym judgment task, clear phonological interference was observed mainly under the condition of the shortest SOA.

GENERAL DISCUSSION

The results of the experiments carried out showed that, when SOA was very short (about under 150 ms), reaction times lengthened regardless of the type of cohort. This means that, under such a range of short SOAs, processing of the cohort had not been completed when the core was presented, so that the cohort and the core had to be processed simultaneously.

The present study also found that in the homophone judgment task reaction times for the synonym pairs lengthened much more than those for the control pairs under this range of short SOAs. Similarly, it was found that in the synonym judgment task reaction times for the homophone pairs lengthened more than those for the control pairs, but only under the shortest SOA at which one could just recognize the words. That is, both phonological interference and semantic interference occurred when SOA was very short, and semantic interference occurred over a wider range of SOAs than did phonological interference.

The results of the error rates were very similar to those of the reaction times, though both phonological and semantic interference were sometimes observed even when SOA was longer.

In general, when SOA is very short it is of great advantage to get only the necessary information for a given task. Therefore, in the synonym judgment task, if phonological activation can be suppressed, only semantic activation of the cohort word is expected to occur before the core word is presented; in the homophone judgment task, if semantic activation can be suppressed, only phonological activation of the cohort word is expected to occur.

From these results, it is reasonable to say that both phonological activation and semantic activation occurred quickly in reading and were not capable of being suppressed. The two kinds of activated information interfered with each other.

These findings suggest the following processes for such interference. When the cohort was presented, both phonological and semantic activation automatically occurred. Under the condition of the shortest SOA, when the core was presented, phonological and semantic information of the cohort were still being processed while phonological and semantic activation about the core were occurring. Therefore, both phonological and semantic information of the cohort and the core were accessed at the same time, and they inevitably interfered with each other. This interference appeared as an increase in the time needed to judge correctly and sometimes as an error judgment. Under the condition of the longer SOA, when the core was presented, phonological and semantic information of the cohort had been processed, and the unnecessary information was ignored. Thus, working memory held all phonological and semantic information of the core but only phonological or semantic information of the cohort, depending on whether the task was a phonological or semantic judgment. There was no interference.

Phonological interference and semantic interference did not always occur in

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the same way. These findings suggest that phonological activation is automatic and inevitable, but that it is easier to ignore phonological information (if this is necessary and there is enough time to do so) than it is to ignore semantic information. The finding that almost all participants in the homophone judgment task were conscious of semantic interference, but only a few participants reported phonological interference, supports this suggestion. Because silent reading, which is difficult for unskilled readers but common among skilled readers, does not require the output of phonological information, the present results might be the favorable consequence of a long learning process in reading. However, these findings about SOA are not consistent with those of Wydell and colleagues (1993). They found phonological interference in a semantic categorization task using Japanese kanji under the condition of a long SOA (e.g., 2000 ms). Whether readers can consciously ignore phonological information might depend on differing task characteristics.

In the present study, both phonological and semantic interference were observed. Both phonological and semantic activation seemed to occur automatically and simultaneously when Japanese kanji were presented. This suggests that there are two routes from orthographic information: to phonological information and to semantic information. Both routes seem to be used simultaneously in Japanese kanji reading.

These findings do not agree with the predictions from the phonological mediation hypothesis, whereby only phonological interference is thought to occur. The universal direct access hypothesis must also be rejected. According to this hypothesis, only semantic interference is expected to occur in Japanese kanji reading by skilled readers. Furthermore, these findings are inconsistent with the orthographic depth hypothesis. Although in the Japanese kanji system grapheme–phoneme mapping is very difficult (i.e., reading involves very deep orthography), the present findings suggest that phonological activation occurs very quickly.

The findings in this study regarding Japanese kanji strongly support the universal phonological principle of Perfetti and Tan (1998): the Japanese kanji seem to be more specialized in offering meaning than the Chinese characters used in Perfetti and Zhang (1995). However, the present findings are a little different from those of Perfetti and Zhang (1995). They found much faster phonological activation than was found in the present study – one which was even faster than semantic activation. A possible reason for this inconsistency is the difference in the function of kanji in Japanese and in Chinese as well as the differences in the materials used (e.g., two-kanji compound words vs. single-kanji characters). Pronunciation of single-kanji characters in Perfetti and Zhang (1995) must have been easier than that of two-kanji compound words in the present experiment.

The universal phonological principle specifies that phonological information and semantic information are not processed in order, but are activated simultaneously from orthographic information (Perfetti & Tan, 1998). Our findings indicate that, even in writing systems such as Japanese kanji, phonological information is activated very quickly and automatically. This supports the claim that "phonological activation itself is general" (Perfetti & Tan, 1998, p. 101).

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APPENDIX

Materials for both Experiment 1 and Experiment 2 and the mean scores in a 5-point scale of familiarity and similarity[a]

	Cohort		
Core	Homophone	Synonym	Control
過剰	箇条	余分	不正
抗争	構想	対立	合図
失踪	疾走	逃亡	娯楽
声明	生命	宣言	便利
意地	維持	根性	価格
経緯	敬意	過程	表情
意見	違憲	忠告	豪華
薄情	白状	冷酷	地域
負傷	不祥	怪我	貯蓄
終身	就寝	一生	利益
懸命	賢明	熱心	地下
警告	渓谷	注意	出席
了解	領海	承知	素朴
推移	水位	経過	泥棒
栄華	映画	隆盛	道徳
衛生	永世	保健	無念
加勢	火星	応援	唐突
冗談	上段	洒落	義務
完了	官僚	終結	中身
階層	回想	等級	案内
以前	依然	過去	年下
家庭	仮定	所帯	平原
介抱	解放	看護	自習
感想	乾燥	所見	普通
官庁	干潮	役所	無事
肝要	慣用	大切	比率
記事	生地	報道	不満
献身	検診	奉仕	破壊
期待	気体	要望	脂肪
先生	宣誓	教員	故郷
臣下	進化	家来	料理
観光	慣行	見物	辞任
後援	公園	支持	妥協
航海	公開	船旅	面目

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APPENDIX (*continued*)

	Cohort		
Core	Homophone	Synonym	Control
嗜好	思考	趣味	契約
視界	司会	展望	報告
指揮	四季	統率	植物
指示	私事	命令	大胆
用意	容易	準備	収入
真相	深層	事実	元気
統治	倒置	支配	試験
基礎	起訴	土台	心配
方策	豊作	手段	無視
警官	景観	巡査	栄光
状況	上京	様子	退化
神父	新婦	牧師	大量
辛抱	信望	我慢	記念
解説	開設	注釈	貧弱
要旨	用紙	大意	布巾
大衆	体臭	庶民	損害
対等	台頭	均衡	弁論
再興	最高	復旧	水面
依頼	以来	要求	住居
簡単	感嘆	平易	芝居
規律	起立	秩序	老後
長所	調書	美点	接続
意向	移行	所存	安全
糾弾	球団	非難	立派
同志	動詞	仲間	天国
登場	搭乗	出現	家柄
監禁	換金	幽閉	発想
勾配	購買	傾斜	説教
事態	辞退	形勢	乱暴
人気	任期	評判	故障
占領	染料	征服	口論
向上	工場	発展	伝説
普及	不朽	浸透	嫌悪
心酔	浸水	夢中	空腹
醜聞	秋分	悪名	浜辺
特異	得意	奇妙	面会
陽気	容器	快活	工夫
契機	景気	発端	反対
正体	招待	本性	挫折

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APPENDIX (*continued*)

	Cohort		
Core	Homophone	Synonym	Control
友好	有効	親善	疑惑
街頭	該当	路上	重点
見当	検討	予想	危機
承認	証人	許可	曖昧
口外	公害	他言	支度
貢献	後見	寄与	無実
優良	有料	上等	言葉
危険	棄権	物騒	作家
Familiarity	2.8	3.0	3.3
Phonological similarity	4.9	1.3	1.1
Semantic similarity	1.0	3.9	1.1

[a]5 = very strongly, 1 = very weakly.

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