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Kanji without Semantics

Phonological Coding of Kanji

by

↑

Hiroko Sotozaki

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Master of Arts
Department of Psychology

Carleton University

Ottawa, Ontario

May, 1995

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RUNNING HEAD: KANJI WITHOUT SEMANTICS

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Abstract

The present research examined phonological coding of Japanese Kanji (ideographic script). Subjects named Kanji words and nonwords in pure (all words or all nonwords) versus mixed (words and nonwords mixed) conditions. Both Kanji words and Kanji nonwords were named faster in the pure as compared to the mixed condition. Kanji words were named faster than Kanji nonwords: This lexicality advantage occurred in both the pure and the mixed condition, suggesting that stored lexical representations play a role in naming Kanji words. Further analyses showed that for fast subjects, naming latencies did not differ between Kanji words versus nonwords nor across pure versus mixed conditions. Subjects classified as slow subjects, however, named Kanji nonwords slower in the mixed than the pure conditions. It is concluded that whereas Kanji words are processed from orthography to phonology via semantics, Kanji nonwords are processed from orthography to phonology bypassing semantics.

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Table of Contents

	Page
Abstract	2
Acknowledgments	3
Table of Contents	4
List of Figures	6
Introduction	7
Background: Japanese orthography	8
Kana	8
Kanji	9
Summary	11
Dual-route models of English and Japanese	12
English	13
Japanese	15
Kana	15
Kanji	17
Present Research	26
method	29
Results	32
Discussion	37
conclusion	44

References	46
Appendix A	54
Appendix B	55
Appendix C	56
Figure Captions	57
Figures	58-66

List of Figures

Figure	Description	Page
1	Dual-model for English.	58
2	Japanese word recognition model.	59
3	Naming latency for Kanji words and nonwords.	60
4	Percent naming errors for Kanji words and nonwords.	61
5	Naming latency for Kanji nonwords consisting of low and high character-frequencies.	62
6	Naming latency for Kanji words and nonwords: Six fastest subjects.	63
7	Naming latency for Kanji words and nonwords: Six slowest subjects.	64
8	Percent naming errors for Kanji words and nonwords: Six fastest subjects.	65
9	Percent naming errors for Kanji words and nonwords: Six slowest subjects.	66

Phonological Coding of Japanese Kanji

Fluent reading of Japanese requires knowledge of two distinct scripts: Kana and Kanji. Effective reading of these scripts uses different processes and requires access to different types of knowledge. Kana is a perfectly regular script in which orthography consistently maps onto sound. Phonological recoding of Kana, therefore, requires knowledge of these mapping principles and can be achieved without accessing semantics. Kanji, on the other hand, is an ideographic script in which orthography does not consistently map onto sound: A given Kanji character is likely to be associated with multiple pronunciations. Accordingly, it has been commonly assumed that the phonological coding of Kanji is always mediated via a semantic module such that there is no direct connection between Kanji orthography and phonology (Kimura, 1884; Morikawa, 1981). Recent research, however, suggests that Kanji can be phonologically recoded without semantic mediation (Sasanuma, Sakuma & Kitano, 1992; Wang, 1988; Wydell, Patterson, & Humphreys, 1993). The purpose of the

present research was to further investigate the possibility that there exists a direct connection between orthography and phonology which can be used to name Kanji.

Background: Japanese orthography

Japanese orthography can be characterized as follows. First, there are sound-based scripts (Kana) and ideographic scripts (Kanji). Second, all Japanese words can be formed from a set of 112 Kana pronunciation units, (see Appendix A). Third, many Japanese words share pronunciations. For example, ha-shi can be "bridge", "chopsticks", or "edge".

Kana. Unlike the English alphabet, a Kana unit consists of either a vowel alone or a combination of a consonant and a vowel (e.g., "a", "ki", "sha"). These combinations cannot be broken down into morphemes (e.g., "ka" ≠ "k" and "a"). Therefore, Kana contains the fundamental pronunciation units of the Japanese language (Kindaichi, 1991). These 112 pronunciation units, either singly or in combination, form all Japanese words.

The pronunciation of any Kana unit is invariant, regardless of its location in a word or how it is combined with other Kana units. Thus, many words share a pronunciation because of the small number of available pronunciation units. For example, **''ha''** is a unit of pronunciation which represents two different words, teeth and leaf. When **''ha''** is combined with other pronunciation units, they form different words: **''ha-na''** (flower or nose), **''ha-ha''** (mother), or **''ha-na-shi''** (a story). The word **''ha-na''** consists of two pronunciation units. The word **''ha-na-shi''** consists of three pronunciation units.

Kanji. Each Kanji character represents a distinct unit of meaning. There are two types of pronunciation: on-reading and kun-reading. On-reading represents the sound of a word. When Chinese characters were introduced to the Japanese language about 1200 years ago, the Japanese language borrowed the Chinese sounds. Thus, on-reading still retains sounds similar to the Chinese language. Consequently, on-reading indicates only the pronunciation, but not the meaning of a word. In contrast, kun-reading is a Japanese way of reading. It

represents the meaning of a word. Because Kana consists of pronunciation units and Kanji represent units of meaning, any Kanji word can be phonetically described in Kana, but not vice versa.

Most nouns can be represented solely in Kanji, whereas verbs, adverbs and adjectives are represented with a combination of Kanji and Kana. If a noun consists of a single Kanji, kun-reading is assigned. If a noun consists of two or more Kanji characters (compound Kanji), on-reading is usually assigned.

Because there are so many homophones in the Japanese language, each word requires a different Kanji character, or a different combination of Kanji characters to distinguish one word from another (e.g., ha-shi,

橋 bridge, 箸 chopsticks, or 端 edge). As a result, approximately 3000 Kanji are required to read a newspaper (Kindaich, 1991).

Two or more Kanji characters may be combined to form a compound Kanji. When Kanji characters are combined, the resulting compound Kanji word is much more precise than a simple Kanji word. Both kun-reading and on-

reading are used for compound Kanji words, but on-reading is more common. For example, the compound Kanji word, 記者 ki-sha (reporter), consists of two Kanji characters. Each individual character has a kun-reading. In kun-reading, each character constitutes a simple word and represents its own meaning, 記す shi-ru-su (report) and 者 mo-no (a person). Therefore, when they are combined to make up a compound Kanji word, the word "ki-sha" represents the integrated meaning of the two words "shi-ru-su" and "mo-no"; a person who reports something. In addition, the word "ki-sha" has a homophone, 汽車 ki-sha (train). Therefore, a compound Kanji word, 記者 ki-sha (reporter) or 汽車 ki-sha (train), specifies the meaning of the pronunciation, "ki-sha". A nonword can easily be created (e.g., 器舎 ki-sha), when an on-reading of other Kanji characters is applied to a compound Kanji word.

Summary. Japanese orthography has two types of scripts, Kanji and Kana. Kana is a perfectly regular script in which orthography consistently maps onto sound. Phonological recoding of Kana is therefore achieved

without accessing semantics. Kanji, on the other hand, is an ideographic script in which orthography does not consistently map onto sound: A given Kanji character is likely to be associated with multiple pronunciations. The pronunciation is chosen depending on the semantic context in which the Kanji character(s) appears. Therefore, most theorists have proposed that the phonological coding of Kanji is always mediated via word-specific semantic knowledge and that there is no direct connection between Kanji orthography and phonology (Kimura, 1984; Morikawa, 1981).

Dual-route models of English and Japanese

The notion that different kinds of processes and knowledge are used to phonologically code Kana and Kanji is paralleled in the English word recognition literature. In English, reading novel words (or nonwords) requires accessing knowledge concerning the general principles governing the mapping of orthography to phonology. In contrast, reading familiar but irregular words (e.g., pint, yacht) requires specific knowledge concerning the pronunciation of individual words: A rule-based system

cannot be used to phonologically code irregular words. Given these parallels, it is not surprising that similar models have been proposed to describe English and Japanese word recognition.

English. In accord with the notion that phonological coding requires both rule-based and word-specific knowledge, a dominant approach has been to assume that two distinct routes exist for translating English orthography to phonology (Coltheart, 1978, 1985; Coltheart, Curtic, Atkins, & Haller, 1993; Coltheart & Rastle, 1994; Paap, McDonald, Schvaneveldt, & Noel, 1987; Paap & Noel, 1991). In dual-route models, it is assumed that there are two independent routes operating in parallel. These are referred to as the lexical route and the assembly route (see Figure 1).

Insert Figure 1 about here

The lexical route is based largely on visual processes and involves accessing orthographic, semantic, and phonological information in the mental/internal

lexicon. The pronunciation of a word is provided by stored knowledge in the mental lexicon. The lexical route is assumed to be frequency-sensitive such that high-frequency words are processed more rapidly than low-frequency words. The assembly route generates phonology by translating graphemes into phonemes via a rule-based conversion. This route is assumed to be generally quite slow and because whole-word representations are not accessed and used in the assembly process, processing along this route is assumed to be insensitive to word frequency. Nonwords (e.g., zint, bave) are assumed to be processed by the assembly route, because there is no stored knowledge for nonwords in the mental lexicon.

When a word is presented, both routes are activated. The lexical route is presumably able to provide the correct phonology for all known words. The assembly route, on the other hand, will provide correct phonologies only for words that have regular spelling-to-sound correspondences (e.g., mint, gave). Irregular words are incorrectly coded via the assembly route because the rule-based system regularizes the

relationship between orthography and phonology. For example, an irregular word such as "pint" will be regularized in such a way as to rhyme with "mint", "tint", "hint".

Japanese. Since the Japanese writing system has both visual and phonological representations, only a dual-route model has been proposed to account for Japanese word recognition processes (Goryo & Sasanuma, 1987). As shown in Figure 2, Goryo and Sasanuma assume that Kana is phonologically recoded via both an assembly and a lexical route, whereas Kanji is phonologically recoded via only a lexical route.

Insert Figure 2 about here

Kana. The rule-based assembly route is well suited for phonologically recoding Japanese Kana: Because Kana is a perfectly regular script, the principles describing the relation between orthography and phonology are easily learned and applied. Direct evidence supporting the notion that Kana is processed via an assembly route has

been reported by Saito (1981). Saito found that naming latencies to Kana varied systematically with the number of pronunciation units. For example, two-unit Kana words (e.g., やま yama: "や ya" + "ま ma" = や ま yama: mountain) are named faster than four-unit Kana words (e.g., せんせい sensei: "せ se" + "ん n" + "せ se" + "い i" = せんせい sensei: teacher).

It should be noted that 1.) the Japanese writing system visual familiarity and word frequency do not always correspond. For example, most Japanese words, especially nouns, are normally written in Kanji. However, if these same words are instead written in Kana, they become visually unfamiliar, even though they may be high-frequency words. Visually unfamiliar Kana words are assumed to be processed primarily by the assembly route. Assembling pronunciation units for these Kana words must, therefore, be faster than processing whole words by the lexical route, since these Kana words do not have the benefit of visual familiarity.

Some words are only written in Kana. Therefore, these Kana words, such as borrowed foreign words

(e.g., テレビ te-re-bi: TV set) are visually familiar. It has been suggested that these visually familiar Kana words are processed by the lexical route as a whole word, like English high-frequency words.

Kana nonwords, on the other hand, are assumed to be processed by the assembly route because there is no corresponding lexical knowledge in the mental lexicon. The results of previous research support this assumption; visually familiar Kana are named faster than visually unfamiliar Kana, and visually unfamiliar Kana are named faster than nonwords (Besner & Hildebrandt, 1987; Herdman, Sotozaki, & Campsall, 1993).

Kanji. Because Kanji characters cannot be broken down into smaller units, it is assumed that only the lexical route processes Kanji words (Goryo & Sasanuma, 1987). Saito (1981) found that the naming latency for Kanji words is the same, regardless of the number of characters in each word. That is, phonological coding of a simple Kanji word does not differ from a compound Kanji word (e.g., 山 = 先生). These results suggest that

Kanji words are processed as a whole, not character-by-character.

It is commonly believed that Kanji words are read via semantic knowledge: Kanji processing proceeds serially from orthography to semantics to phonology (Kimura, 1884; Morikawa, 1981). Semantic checking of a Kanji word is necessary in order to select the correct pronunciation of a word. If the pronunciation is selected without semantic checking, confusion between on-reading and kun-reading of the word will occur. When a Kanji word is presented, the meaning of the word must be assessed as a whole, and then the correct pronunciation can be generated.

It has recently been suggested, however, that phonological coding may occur in parallel with semantic processing of Kanji. Wang (1988, see also Nomura, 1981; Saito, 1981) conducted two experiments using a visual search paradigm. In Experiment 1, participants were asked to scan ten word lists in order to find an item which was either orthographically, phonologically or semantically related to a target. The results indicated

that detection of an orthographically similar item was performed the quickest. More interestingly, the time to detect phonologically and semantically related items did not differ. This suggests that phonological and semantic processing of Kanji words occurs in parallel, such that the time to retrieve both types of information does not differ. In Experiment 2, two- and four-character Kanji words were used in the search task to determine whether the number of characters per word affected the processing time. The results showed that the number of characters did not affect search times for phonological and semantic processing of related items. These results suggest that orthographic processing occurs first, followed by parallel activation of phonological and semantic codes.

The notion that phonological and semantic coding of Kanji occurs in parallel is further supported in studies of dyslexics. Dyslexic patients can be classified into two distinct clinical categories. One consists of patients who have a problem using word-specific information and in particular, who have difficulty in naming irregular words: These patients tend to generate

erroneous regularization errors. This disability is referred to as "surface dyslexia" (Coltheart, Masterson, Byng, Prior & Riddoch, 1983). The other type of dyslexia is "phonological dyslexia" (Newcombe & Marshall, 1985) in which the patient demonstrated difficulty in using phonological rules. Phonological dyslexics have particular trouble naming nonwords or in engaging in letter-by-letter reading.

Research investigating surface dyslexia has provided converging evidence concerning the nature of processing along the lexical route. In English patients, Coltheart et al. (1983) distinguished two typical surface dyslexic readings: (1) phonological reading, and (2) confusion in the meaning of homophonic words. Phonological reading is manifested by the incorrect reading of irregular words. The confusion in the meaning of homophonic words is manifested by misunderstanding homophonic words (e.g., "bury" and "fruit" on a tree (berry)). Surface dyslexics presumably have suffered a disruption to the connections between orthographic and semantic descriptions in the mental lexicon (Coltheart et al., 1983; Kay & Patterson,

1985). The orthographic information is unable to access the semantic representation. Therefore, the pronunciation depends solely on the phonological rules.

In Japanese, dyslexics have been categorized into four groups (Sasanuma, 1975, 1980a, 1980b, 1984, 1985; Sasanuma & Fujimura, 1972): (1) a selective impairment in Kana processing without fluency (Broca's aphasia), (2) a selective impairment in Kana processing with fluency (conduction aphasia), (3) a selective impairment of Kanji processing (word-meaning aphasia), and (4) better performance in Kana than in Kanji (severe Wernicke's aphasia). Patients in (3) and (4) can read aloud or write Kana, but not Kanji, and are therefore referred to as surface dyslexics.

The surface dyslexics in group (3) are referred to as Gogi (word-meaning) aphasics (Imura, 1940, 1943; Sasanuma & Monoi, 1975). These patients show a selective impairment of Kanji processing with a remarkable preservation of Kana processing. The errors displayed by these patients typically represent the substitution of homographic characters in spelling, or the inappropriate

reading of homographs (Sasanuma, 1980a, 1980b). Sasanuma et al. (1975) discussed a patient, M. U., who could dictate words in Kana with no difficulty, but who could not assign the correct Kanji. This patient generated incorrect Kanji characters to the Kana words based solely on the pronunciations. Thus, although the sounds of the generated Kanji were correct, the meaning associated with these Kanji were incorrect (e.g., 新聞 shin-bun: "newspaper" was written 進 susumu: "progress" and 文 "bun": "sentence").

The dyslexic patients in (4) exhibit better performance in Kana than in Kanji, similar to what is observed in those with Gogi aphasia (group 3). However, the types of errors made differed across these two groups. Group (4) made on/kun confusions (Sasanuma, 1985), but typically did not exhibit the peculiar substitution of homographic characters in spelling, or the inappropriate reading of homographs that the Gogi aphasics produce. Sasanuma (1985) discussed a patient, S.U. as a typical patient in group (4). The words successfully read aloud by S.U. were those in which he

could show understanding by matching pictures to the words. The main errors made by S.U. were on/kun confusions.

These two types of dyslexia can be interpreted using the Japanese word recognition model shown in Figure 2. There is a main lexical route from orthography to phonology via semantics, and a subpath from orthography to phonology that bypasses semantics. For the Gogi aphasics, there is presumably a disruption from orthography to semantics. Therefore, the pronunciations generated by these dyslexics occur via the sub-path which directly connects orthography to phonology in the lexical route. Because semantic information was not available, Kanji characters were selected using visual familiarity, and applied to Kana words with reference to their pronunciation only. As a result, the patients named the Kanji word which shared the pronunciation. Therefore, Gogi aphasics are able to read Kanji words aloud but without comprehension. This type of surface dyslexia is rarely found in English surface dyslexic patients. In the case of English dyslexia, the presence of semantic

errors is sufficient basis for the diagnosis of phonemic dyslexia (Patterson & Kay, 1982; Sasanuma, 1985).

For the fourth group of patients, the connection between semantics and phonology is presumably damaged. Patients in this group, such as S.U., have the ability to name Kanji words for which they can access the meaning. If the meaning of a Kanji word cannot be accessed, however, then the word cannot be named, and on/kun confusion errors are often made. The evidence that S.U. failed to read aloud Kanji with reference to pronunciation only suggests that the sub-path may be disrupted for some reason (Sasanuma, 1985).

Further evidence challenging the assumption that phonological coding of Kanji is necessarily mediated by semantics has been reported by Sasanuma, Sakuma and Kitano (1992). Sasanuma et al. (1992) showed that demented Japanese patients could pronounce Kanji words without comprehension until the very advanced stages of their dementia. In their experiment, Sasanuma et al. (1992) examined three Japanese patients with Alzheimer-type dementia over a period of 26 months. Two types of

tests were administered to the patients: The Kanji Pronunciation-Comprehension Test (K.P.C.T.) and a battery of Higher Brain Function Tests (H.B.F.T.). The K.P.C.T. consisted of 50 simple and compound Kanji words. Comprehension of the Kanji words was tested by matching them with pictures. The H.B.F.T. evaluated four cognitive functions: (1) orientation, (2) short-term and long-term memory, (3) linguistic abilities, including semantic, syntactic and phonological processing, and (4) visuospatial constructive abilities. The test was administered every six months at the early stages of the disease and every three months at later stages. Although all three patients exhibited nearly perfect performances in pronouncing Kanji words until very advanced stages of dementia, their comprehension progressively deteriorated as indexed by their decreased performance in the word-picture-matching test. Throughout the testing, most errors made in the cognitive domain were related to semantics (e.g., categorization task).

Present Research

To date, the strongest evidence that there exists an orthographic to phonological subpath for naming Kanji has been provided by clinical research with dyslexic patients. The goal of the present research was to investigate the role of this orthographic to phonological sub-path in a non-clinical population. To do this , a list composition manipulation was used in which participants were required to name Kanji words and nonwords that were either presented in a pure block (all words or all nonwords) or in a mixed block (words and nonwords together). The list composition manipulation was included to differentially orient processing of Kanji within the lexical route.

List composition manipulations have been used in studies on English word recognition to examine differential orienting toward lexical versus assembled phonology (Baluch & Besner, 1991; Herdman, LeFevre & Greenham, 1994; Monsell, Patterson, Graham, Hughes, & Milroy, 1992). Monsell et al. (1992) required participants to name words and nonwords in either pure or

mixed blocks. Whereas naming latencies to words did not differ across blocks, nonwords were named faster in the pure as compared to the mixed block. This finding suggests that phonological coding is flexible. In the mixed block, both the assembly and the lexical route were involved: The system waited for a lexically derived code to be generated thereby slowing output to the nonwords stimuli.

Further evidence of flexible phonological coding has been reported by Herdman et al. (1994) who examined naming latencies to pseudohomophones (e.g., phocks). They found that pseudohomophone naming was sensitive to the frequency of their corresponding base-words but only when real words were presented in the stimulus lists. When the stimulus lists did not include real words, pseudohomophone naming latencies were not influenced by base-word frequency. This suggests that the inclusion of real words in the stimulus lists oriented processing toward the frequency-sensitive lexical route.

Baluch and Besner (1991) investigated the effects of list composition on the oral reading of Persian.

Frequency effects were greatly attenuated in the mixed list condition. One interpretation is that including nonwords in the stimulus lists oriented processing toward the nonlexical route. Because processing along this route is insensitive to word-frequency, an increased contribution from the nonlexical route diluted the overall effects of frequency.

In the present research, list composition was manipulated in an attempt to orient processing toward or away from semantically-mediated coding. In the pure condition, knowledge about Kanji words was assumed to be stored in the mental lexicon, thus, these words are assumed to be processed quickly as whole units (Kaiho & Nomura, 1983; Nomura, 1981; Saito, 1981). Knowledge about Kanji nonwords, on the other hand, was assumed to be not stored in the mental lexicon, thus, these nonwords were assumed to be processed character-by-character. Accordingly, a simple lexicality advantage was predicted where Kanji words would be named faster than Kanji nonwords. Moreover, because Kanji nonwords are processed character-by-character, nonwords consisting of high-

frequency characters should be faster than nonwords consisting of low-frequency characters.

In the mixed condition, semantic checking had to occur prior to phonological coding to determine whether the Kanji stimulus was a word. If the stimulus was a word, the pronunciation could be provided from the mental lexicon via semantic mediation with presumably little cost as compared to the pure condition. If the stimulus was a nonword, then processing had to be shifted away from semantic mediation and toward the orthography to phonology subpath. This initial semantic check and resultant shift requires additional time such that naming latencies for Kanji nonwords should be longer in the mixed as compared to the pure condition.

Method

Participants. Thirty two Japanese students who have lived in Canada for less than three years served as participants. The ratio of male and female was 7 to 25. Their ages ranged from 18 to 30. Of 32 participants, the eleven completed high-school education, the seven completed college, the five completed university, and the

ten are attendant university. Participant were paid \$15 for participating in the experiment.

Apparatus. An IBM-type 80286 computer equipped with a Digitek Electronics I/O board was used to present letter strings on a Samsung SF12 video monitor and to record responses. Naming responses were detected using a Beyerdynamic headset (containing a built-in boom microphone) connected to a Grason-Stadler model E7300A-1 voice activated relay interfaced to the Digitek I/O board. Participants were seated approximately 50 cm from the video monitor. A micro-switch located on a button box was used to initiate trials. Response latencies were accurate to 1 ms.

Stimulus Materials. An example of the stimuli sets is shown in Appendix B. In Japanese orthography, Kanji word frequency and character frequency do not always correspond. Kanji processing may vary depending on whether a single character is used as a simple Kanji word or as part of a compound Kanji, or whether it is read by on-reading or kun-reading. In the present experiment, all items were compound Kanji. The Kanji words and

nonwords were matched using the National Language Institute norms (1978) such that character frequency was constant across words and nonwords. Visual complexity and initial phoneme were matched across stimulus types. Any given Kanji character was shown only once.

Compound Kanji words. A total of 80 compound Kanji words were used as test stimuli. The Kanji words were composed of two Kanji characters (a total of four pronunciation units per word). All the compound Kanji words were nouns, and used on-reading.

Compound Kanji nonwords. Most Kanji characters have both on/kun-readings. The dominance of reading in each Kanji character is determined by the frequency of reading of each Kanji character as a simple Kanji or part of compound Kanji word. A total of 160 Kanji characters were used to compose of 80 Kanji nonwords. All Kanji nonwords were composed of two Kanji characters (four pronunciation units per word). Of them, 140 Kanji characters were on-reading dominant, 11 Kanji characters were kun-reading dominant, and the remaining nine Kanji characters have little reading dominance. In addition,

pronunciations of nonwords were not shared with real words.

Design. A 2 (Condition: pure, mixed) x 2 (Type: word, nonword) within-groups repeated measures design was used. The pure condition had a block of 40 Kanji words versus a block of 40 Kanji nonwords. Stimuli were presented randomly within a block. The mixed condition contained 40 compound Kanji words and 40 compound Kanji nonwords. Within the mixed condition, the order of words and nonwords was randomized.

There were 160 test trials preceded by 8 practice trials. The order of the pure and mixed blocks was counterbalanced over the participants. List 1 and List 2 were identical, but the order of the stimuli was reversed. The Kanji word and nonword stimuli sets are shown in Appendix C.

Procedure. Participants fixated on a centrally presented asterisk and initiated a trial by pushing a button. 1000 ms later the asterisk disappeared and a stimulus item was displayed. The stimulus item was removed from the screen when a naming response was

detected. Naming latencies were measured from the onset of a stimulus item. Participants were instructed to pronounce stimuli by either on-reading or kun-reading, whichever first came to mind.

Results

Naming latencies. Median naming latencies to correct responses were computed for each subject. Figure 3 shows these latencies as a function of stimulus and condition. Latencies were examined with a 2 (Stimulus Type: words, nonwords) X 2 (Condition: pure, mixed) repeated measures ANOVA. As predicted, a main effect of Stimulus Type was obtained, with Kanji words being named faster than Kanji nonwords (839 ms versus 1079 ms), $F(1,31)=8.34$, $MSe=6785$, $p < .01$. Naming latencies were also significantly faster in the pure condition (938 ms) than in the mixed condition (980 ms), $F(1,31)=170.17$, $MSe=10890$, $p < .001$. However, the interaction between condition and stimulus type was not significant ($F < 1$).

Insert Figure 3 about here

Error data. Figure 4 shows these percentage error as a function of stimulus and condition. The means were examined with a 2 (Stimulus Type: words, nonwords) X 2 (Condition: pure, mixed) repeated measures ANOVA. The main effect of Stimulus Type was significant, indicating that more pronunciation errors were made on Kanji nonwords than Kanji words (16.3% versus 4.3%), $F(1,31)=128.0$, $MSe=5.7$, $p<.001$. The main effect of Condition and the interaction between Condition and Stimulus Type was not significant ($F< 1$).

Insert Figure 4 about here

Analysis of character frequency. For the present experiment, character frequency was controlled, but not word frequency. Therefore, Kanji nonwords were examined with a 2 (Stimulus Type: high-frequency, low-frequency) X 2 (Condition: pure, mixed) repeated measures ANOVA. The analysis showed that the high-frequency characters were pronounced faster than the low-frequency characters

(1036 versus 1127 ms) in both pure and mixed conditions, $F(31, 1)=44.7$, $MSe=6041.8$, $p < .001$, (see Figure 5).

Insert Figure 5 about here

Individual differences in naming speed. With the evidence that slow readers are more likely to be affected by list composition manipulations (Herdman et al., 1994), it was assumed that fast and slow participants showed different patterns of performance. Therefore, fast and slow participants were selected from the sample based on the naming latency of Kanji words in the pure condition. In particular, scores falling above the median of the latency distribution might weaken the effect of the interaction between Condition and Stimulus Type. A median-split analysis of the data did not reveal any significant interaction between Condition (pure versus mixed) and Stimulus Type (word versus nonword) by Subjects (fast versus slow). The data were further explored by examining the six fastest and slowest participants. Given the exploratory nature of this

analysis, any conclusion from the analysis will be tentative. The six fastest and slowest participants were analyzed with a 2 (Condition: pure, mixed) X 2 (Stimulus Type: word, nonword) X 2 (Subject: fast, slow) ANOVA with repeated measures on the first two factors. As expected, the six fastest participants named the test items faster than the six slowest participants (771 ms versus 1103 ms), $F(1, 10)=22.73$, $MSe=75487.8$, $p < .001$. The main effect of Stimulus Type was repeated, where Kanji words were named faster than Kanji nonwords (851 ms versus 1067 ms), $F(1, 10)=46.7$, $MSe=12022.6$, $p < .001$. Most interestingly, the three-way interaction was significant, $F(1, 10)=7.8$, $Mse=3907.1$, $p < .01$ (see Figure 6).

Insert Figure 6 about here

Simple main effect analyses were conducted. For the six fastest participants, there were no significant effects. For the six slowest readers, Kanji nonwords were named slower in the mixed (1341 ms) than in the pure condition (1201 ms), $F(1, 10)=8.3$, $MSe=3907.1$, $p < .01$.

In contrast, Kanji words did not differ across pure versus mixed conditions. The results are shown in Figure 7.

Insert Figure 7 about here

Errors made by the six fastest and slowest participants were examined with a 2(Condition: pure, mixed) X 2(Stimulus Type: word, nonword) X 2(Participants: fast, slow) repeated measures ANOVA. There was no significant difference in Participants and Conditions in terms of making errors, suggesting that there is no trade-off between speed and accuracy. However, Kanji nonwords were named incorrectly more than Kanji words (18.4% versus 6.2%), $F(1,10)$, $MSe = 7.9$, $p < .001$ (see Figure 8 and Figure 9).

Insert Figure 8 & 9 about here

Discussion

Theorists have generally assumed that phonological coding of Japanese Kanji must be mediated by semantics (Kimura, 1984; Morikawa, 1981). Recent research suggests, however, that there may exist a subpath which bypasses semantics such that phonological coding of Kanji may also be achieved via a direct connection between orthography and phonology (Sasanuma et al., 1992; Wang, 1983; Wydel et al., 1993). The present research investigated the role of this orthographic to phonological subpath using a list composition manipulation designed to orient processing toward or away from semantically mediated coding: Participants were required to name Kanji words and nonwords in pure versus mixed conditions. The results showed that Kanji words were named faster than Kanji nonwords in both the pure and the mixed conditions. A simple account of this finding is that Kanji words are processed quickly as whole-units (Kaiho & Nomura, 1983; Nomura, 1981; Saito, 1981) and benefit from access to corresponding word-knowledge stored in the mental lexicon. Kanji nonwords,

on the other hand, are processed in a slow character-by-character manner and do not benefit from access to whole-word representations in the lexicon. The assumption that nonwords are processed character-by-character was supported by the finding that nonwords consisting of high-frequency characters were named faster than nonwords consisting of low-frequency characters.

In accord with previous research (Kimura, 1984; 1983; Morikawa, 1981), phonological coding of a Kanji word is presumably mediated by semantics: The orthographic configuration of a Kanji word activates a specific semantic representation which then accesses the appropriate phonological information. This semantically mediated route should operate effectively during naming of Kanji words regardless of the list composition. Phonological coding of a Kanji nonword does not benefit from semantic mediation (Kaiho & Nomura, 1983; Nomura, 1981; Saito, 1981). In the pure (nonword) condition, therefore, it was expected that the semantic route would be de-activated such that nonword processing would proceed via a subpath which bypasses semantics and which

is based on character-by-character connections between orthography and phonology. In the mixed condition, however, the presence of words in the stimulus lists was assumed to orient processing (see Baluch & Besner, 1991; Herdman et al., 1994; Monsell et al., 1992) such that the orthographic-to-semantic route remained engaged: An initial, but unsuccessful, check for a semantic representation of the nonword would occur. The results of the present research show that the list composition manipulation was robust insofar as naming performance was slower in the mixed as compared to the pure condition. In the overall analyses, however, list composition did not differentially slow naming of Kanji words versus nonwords. Based on additive factors logic, one interpretation of this null interaction is that list composition slowed processing at a stage in the word recognition system that is insensitive to the lexicality of the item being processed. Another possibility, however, is that processing along the orthographic-to-semantic route and the orthographic-to-phonological subpath occurs in parallel. According to this view, the

initial semantic check in the mixed condition did not result in additional slowing of nonword naming because phonological coding of the nonword items proceeded in parallel along the subpath.

Previous research has shown that in word recognition tasks, list composition effects occur most reliably with participants who are classified as slow readers (e.g., see Herdman et al., 1994). Fast readers presumably have efficient word recognition abilities which are possibly automatic and thereby immune to list composition and other strategic effects (LaBerge & Samuels, 1974; Stanovich, 1980). Accordingly, an analysis of a subset of fast versus slow namers was conducted in the present research. Fast participants showed relatively small (32 ms) effects of list composition which were undifferentiated across Kanji words versus Kanji nonwords. The slow participants showed a larger (56 ms) effect of list composition. More interestingly, for the slow participants, list composition interacted with stimulus type. Whereas naming of Kanji words was only minimally (28 ms) affected by list composition, Kanji

nonwords were named 140 ms slower in the mixed than in the pure condition.

The interaction between list composition and stimulus type shown by the slow participants clearly negates the interpretation that list composition slowed processing at a stage in the word recognition system that is insensitive to the lexicality of the item being processed. Moreover, the notion that processing along the orthographic-to-semantic route and the orthographic-to-phonological subpath occurs in parallel does not hold for these participants. Instead, the pattern of response times associated with the interaction is consistent with the notion of a functionally serial architecture. According to this position, the orthographic-to semantic route was de-activated in the pure-nonword condition such that nonwords were processed along the orthography-to-phonology subpath. In the mixed condition, the presence of words in the stimulus lists oriented processing toward semantic mediation: There was an initial semantic check which resulted in additional slowing in processing of the nonwords. The additional slowing was observed because,

for the slow participants, phonological coding of nonword items does not proceed in parallel along the subpath. Instead, for these participants, the word recognition system is serial such that an attempt to process the nonwords along the orthography-to-semantic route compromises the use of the orthographic-to-phonological subpath.

The patterns of performance shown by fast versus slow participants are consistent with extant models describing individual differences in word recognition ability (e.g., Laberge & Samuels, 1974; Perfetti, 1985; Stanovich, 1980). Fast participants have automatic word recognition which is immune to list composition effects. Slow participants have inefficient (nonautomatic) word recognition which can be modulated by list composition and presumably other strategic factors. The finding that word recognition is flexible in slow participants is nontrivial as it suggests a system in which processing can be modulated in a relatively subtle fashion, although at some cost in terms of speed of processing. This flexibility of processing can be accounted for by the

notion of a modular cognitive system. According to this view, a cognitive structure may become modular to the extent that it operates on its own and interacts with other structures only via input to the module and output from the module. The modularity represents the automaticity of cognitive processes. When the modularity of cognitive structures is fully developed, the input/output processing becomes insensitive to extraneous variables, such as list composition. Thus, the process may be considered cognitively impenetrable (cf. Fodor, 1983). However, as the skill develops and it becomes more modular, it also becomes less flexible. Note, however, because individual differences were examined post hoc, patterns of performance across fast versus slow participants should be interpreted with some reservation. Stronger conclusions concerning individual differences require further research in which participants are classified using converging measures of word recognition and/or reading ability.

In general, however, the results of the present research are consistent with the notion that processing

of Kanji can take place along both a semantically mediated route and via a subpath connecting orthography to phonology. As discussed above, this model can account for the patterns of dyslexia patients (Sasanuma, 1980a, 1980b, 1984; Sasanuma & Fujimori, 1972; Sasanuma & Monoi, 1975). For example, the finding that neurological patients (Sasanuma et al., 1992) are able to pronounce Kanji stimuli until advanced stages of dementia without comprehension suggests that performance must be based on a connection between orthography and phonology. In essence, these patients treat Kanji words as nonword stimuli and presumably generate pronunciations based on the visual familiarity of each character.

Conclusions

The present research is consistent with the hypothesis that Japanese Kanji can be phonologically coded along an orthographic-semantic-phonological route and via an orthographic-phonological subpath which bypasses semantics. Semantic mediation is required to ensure correct reading of Kanji words. Kanji nonwords, on the other hand, cannot be semantically mediated and

thus rely on character-by-character processing along the subpath.

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Appendix B

Example of Stimuli SetsCompound Kanji WordsCompound Kanji Non-words

心配

偏見

間作

銘径

(care,shinpai) (prejudice,henken) (kansaku) (meikei)

Appendix C

Kanji word and nonword stimuliWord-1

伸展	博識	態勢	全盛	炭鉦	定点	芸能	降雪	方法	街頭
切望	英才	統編	村稅	安心	推測	大臣	伝染	學問	確認
单独	階層	難航	制約	白米	轉勤	形式	遠足	總代	放任
相談	再審	敗走	實現	容積	水産	満月	緑日	優越	製品

Word-2

店內	水洗	新聞	材木	目的	寢台	配達	仏門	散文	名案
毛筆	高校	闘争	混乱	建築	警察	体験	追伸	平靜	音楽
動物	金融	改造	公演	労働	検温	存在	西洋	精神	減速
反对	撮影	運命	犯罪	親類	輕快	活躍	必要	後半	源泉

Nonword-1

読幸	節堂	粉雜	旦監	晚映	崎限	東覚	段卷	每整	風院
簡腹	身銀	等発	軍僕	言塩	数民	追合	君低	版陽	遊岩
館片	返寸	功鮮	属越	面内	殿候	探北	代最	想線	貫界
程権	械短	党元	論傾	服導	空南	参放	庭真	答丸	買根

Nonword-2

責撃	催珍	件阪	例頼	育額	品介	均殺	縫飲	倍般	忘枚
暗竹	納惠	円感	農衛	番青	杯督	明善	講郡	用綿	栽型
男各	彈信	採变	点嚴	連清	号草	高千	妻願	投团	電画
員說	提財	海燃	域計	接官	郎晋	設題	天振	増石	属特

Figure Captions

Figure 1. Dual-route model for English.

Figure 2. Japanese word recognition model (modified from Goryo, 1987) .

Figure 3. Naming latency for Kanji words and nonwords.

Figure 4. Percent naming errors for Kanji words and nonwords.

Figure 5. Naming latency for Kanji nonwords consisting of low versus high character-frequency.

Figure 6. Naming latency for Kanji words and nonwords: Six fastest participants.

Figure 7. Naming latency for Kanji words and nonwords: Six slowest participants.

Figure 8. Percent naming errors for Kanji words and nonwords: Six fastest participants.

Figure 9. Percent naming errors for Kanji words and nonwords: Six slowest participants.

Lexical Route

internal lexicon

printed word

Assembly Route

Dual-route model for English

Japanese word recognition model

(modified from Goryo, 1987)

Kanji words and nonwords

Overall

Character Frequency

Six Fastest Participants

Six Slowest Participants

Six Fastest Participants

Six Slowest Participants

END

0|4-06-9|6

FIN