

ACCESSING THE JAPANESE MENTAL DICTIONARY THROUGH THE JAPANESE WRITING SYSTEMS

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Abstract: This study synthesizes conflicting models of Japanese lexical access and word recognition, and the way in which the four orthographic types (katakana, hiragana, romaji, and kanji characters) in the modern Japanese writing system access the mental lexicon in processing written Japanese words and text.[1] Japanese research into the processing requirements of a mixed orthography sheds light on the basic questions of word recognition and lexical access in psycholinguistics, and this paper reviews this rich paradigm of psycholinguistic research in an attempt to explain how lexical access becomes word recognition in processing written Japanese when presented in exclusively syllabary, Chinese kanji characters, or mixed scripts.

Keywords: kanji, kana, hiragana, katakana mental lexicon, lexical access, word recognition, access routes

1. INTRODUCTION

The history of the Japanese scripts evolves from early adaptations of Chinese characters through to the legislated literacy of recent times, with the end result being two kana syllabaries, which match the relatively simple syllabic structure of the language, and a large inventory of logographic kanji which can have varying pronunciations. The issues in lexical access for Japanese words are complicated by the very fact that Japanese does not have a single script type. Instead it has three script types,[2] two of them syllabaries and one of them a logographic system based on Chinese characters borrowed and adapted over the centuries. Even though Chinese characters (*hanji*) are employed in Japanese, the structuring of the mental dictionary for

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[2] Actually, with the increasing use of the Latin alphabet-based *romaji*, it now has four script types. Where Japanese may or may not be the most complicated orthography among the world's languages, it now has the unique distinction of employing all three extant forms of transferring sound to written symbol, namely, the alphabetic, the syllabary, and logographic writing systems.

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Japanese *kanji* is in many ways quite different from that for Chinese characters. Perhaps most vibrant areas of research for Japanese psycholinguistics have been tied to the architecture of its orthographic system. Japanese research has been keenly interested in the structure of the mental lexicon because of possible differences in syllabic kana vs. logographic kanji processing, as well as in possible differences in processing Japanese vs. non-Japanese orthographic layouts. The early literature entertained the notion that the two types of writing system, kana syllabary vs. kanji logographs, would employ different mechanisms and perhaps even different sides of the brain.[3]

The expectation was that kana syllabaries would be processed through phonological decoding, whereas kanji would allow direct access to meaning. In this respect, the two writing system types, one based on a phonological principle and the other based on the same morphological principle as Chinese hanji, would ostensibly rely on different processing principles. The expectation was, furthermore, that the morphologically-based kanji would allow direct whole-word access to meaning direct from the orthography, while the phonologically-based kana would have to go through the step of phonological decoding to get at meaning. This expectation was further enhanced by the fact of extreme regularity in the relationship of the hiragana and katakana syllabaries to their respective syllables. The facts are, as we shall see, otherwise, and in some ways reminiscent of research findings for other languages while in other ways quite different.

Modern psycholinguistic concerns with the role of 'top-down' processing mechanisms vs. 'bottom-up' processing mechanisms are complemented by these Japanese inquiries which assess the contribution of, as well as possible interaction between, graphemic, phonemic, and semantic information in kana vs. kanji reading. And so, we attempt in this paper to present an overview and synthesis of Japanese psycholinguistic research into how these aspects of written Japanese affect word recognition in that language. We also attempt to relate these findings to the cognitive processes that underlie lexical access for visual word recognition and reading for languages in general. Very simply, we attempt to ascertain whether the four orthographic types (katakana, hiragana, romaji, and kanji characters) in the modern Japanese writing system differ significantly in the way they access the mental lexicon.

2. KANJI

As is well-known, Japanese employs kanji characters borrowed from the morphemically-based logographic system developed for Chinese orthography. Beginning in the seventh century, kanji were imported and transduced into Japanese orthography from Chinese hanji in four separate and distinct historical periods. Massive borrowing transformed the vocabulary and

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[3]Of course, what such early studies confounded was that the nature of the cognitive task is what predicts laterality preferences, not the stimulus types itself. Kess and Miyamoto's (1996) overview of the Japanese experimental literature on kanji processing shows a clear interaction between the experimental stimuli involved vs. the specific tasks posed. The stimulus type is not what drives the particular cognitive demands arising from the various types of experimental tasks asked of subjects when dealing with kanji. Although the stimulus type *per se*. makes its own specific processing demands, it is the cognitive task type that is the crucial consideration in evaluating laterality preferences when subjects deal with logographic hanji or kanji. For example, experimental studies which employ graphemic processing tasks in which a pair of symbols are presented simultaneously to just one visual field for graphemic identification often find a left visual field (and hence right hemisphere) advantage. This generalization is hardly surprising, given that the right hemisphere is dominant for gestalt pattern-matching, and hence responsible for processing of the configurational aspects of kanji and hanji. Even here, depth of processing encouraged by exposure times has an effect. For example, in reviewing previous work on laterality preferences and kanji/hanji processing tasks, Hasuike, *et al.* (1986) observe that previous studies which found superiority for the non-linguistic, or pattern-matching gestaltic, right hemisphere in hanji processing did so when there were very short exposure durations for hanji stimuli. Such stimuli must have elicited this right hemispheric superiority because they were essentially treated as non-linguistic stimuli. When stimulus exposure durations exceeded 50 msec, these right hemisphere superiority effects did not appear. Conversely, one must admit that the non-analytic, non-phonological, right hemisphere. has some input at the earlier stage of hanji processing, and that graphemic information is being registered in some way by the cognitive mechanisms allied to interpretative procedures.

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established new patterns for the creation of lexical items. In Chinese, their use constitutes the only writing system, but in Japanese, the use of Chinese characters is complemented by two other sets of orthographic symbols, both of which are syllabic in origin and themselves ultimately derived from kanji simplifications.[4]

But reading written Japanese is not as simple as processing a limited number of single characters which represent single words with single readings. A number of orthography-specific requirements interact to make kanji processing a many-faceted cognitive task in Japanese. For example, Japanese kanji characters have varying pronunciations (or 'readings'), and this fact arises from the history of their implementation. There are two possible types of reading for a given kanji a given kanji can have a native Japanese reading, known as its *kun*-reading, or it can have an imported Chinese, or *on*-, reading. Furthermore, the Chinese *on*-readings can also vary; a given kanji can have *on*-readings which correspond to the four periods of historical borrowing from China they arrived in.

One of the key processing questions for kanji recognition involves the role of phonological vs. semantic factors, and their possible application in a parallel mode vs. a sequential mode. Similar to the debate in Chinese lexical access, can meanings of words written in kanji be understood even when their phonetic codes are not retrieved from the written transcriptions? The problem of phonological activation in Japanese, however, is complicated by the problem alluded to above, namely, that there is usually more than one reading for a given kanji. A second question is whether the much-lauded semantic quality of the component radicals in individual kanji characters actually have much to do with lexical access, that is, whether they are employed during the semantic interpretation of the character. The third important question has to do with the fact that many common and technical Japanese words are typically compounds, and not words represented by single kanji. The question here is whether compound kanji are recognized and processed as integrated units, or whether their successful recognition is contingent upon the recognition and processing of their kanji individual components.

We will attempt to survey some of the experimental answers to these basic questions below, largely focussing on Japanese research reports, in an attempt to elucidate what we have learned about the architecture of the mental lexicon for that language.

2.1. Phonological Activation

Chinese orthography, the source from whence Japanese kanji are derived, is morphemically-based. Yet Chinese allows, and may even sometimes require, phonological information to be accessed during its word recognition procedures. The majority of Chinese logographs are phonographs (Wang, 1981), and it is this type of logograph which has typically drawn our attention in questions of automatic phonological activation in Chinese lexical access and word recognition. Phonographs exhibit two possible constituent parts traditionally, there is a radical or signific, usually on the left side of the character, which refers to meaning; on the right side

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[4] According to recent statistical analyses of kanji in daily usage, just over 3000 of the possible 50,000 kanji are typically used in contemporary magazines and newspapers. In fact, less than 200 kanji account for 50% of daily usage, while 1000 kanji account for 90% of daily usage. An inventory of 2000 kanji account for 99%, suggesting that the actual number of discrete but frequently-used kanji is considerably less than one expects (see Nomura, 1984). Statistical data even point to a decline in the use of kanji; for example, novels written in 1900 employed text which was 39.3% kanji, while those written in 1950 employed only 27.5% (Nomura, 1984). The same is true when one charts the decline in kanji usage in major Japanese newspapers published during the Meiji (1868-1911), Taisho (1912-1925), and Showa (1926-1989) eras. The use of kanji in the 'big newspapers' aimed at bureaucrats and intellectuals was at first extremely high, with an occurrence rate of kanji close to 65%. Government notices cited in such papers exhibited a kanji occurrence rate which went as high as 95%. High frequencies for kanji were at first observed even with the 'small newspapers' aimed at the common people; here the occurrence rate was reported at around 55%. Throughout the last century of Japanese newspapers, however, the occurrence rate for kanji has decreased steadily, spurred on by governmental decrees reducing the number of officially approved kanji and the attempt to make newspapers available to a larger readership (see Kajiwara, 1982).

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of the character, there is often a phonetic which refers to pronunciation (see Chen and Yuen, 1991).[5] And it was this system which, in principle at least, was borrowed into Japanese. Although the characters imported from China into Japanese often retain these phonetic radicals, these are nowhere as reliable or useful in reading Japanese kanji as they are in Chinese. In fact, the percentage of phonetic radicals with reliably correct readings for a given kanji are very limited in Japanese. This basic difference in and of itself makes the discussion of phonological activation inherently different for character recognition in Japanese discussions of lexical access.

A central issue in Chinese hanji processing has been related to this dichotomy between phonological and semantic properties of characters, and attempts have made to examine whether the phonological properties of a given hanji character must be invoked before its meaning can be accessed. The issue of phonological activation is, of course, worthy of interest whether or not there are so-called phonetic radicals within the logographic symbols for either language. It is just that their presence in Chinese has been more closely tied to such inquiry in Chinese psycholinguistics, in Japanese considerably less so. Nevertheless, the same psycholinguistic question arises in respect to Japanese kanji processing, namely, whether phonological and semantic processing interact in parallel or sequential modes when the mental dictionary is consulted. One view, the speech recoding view, claims that character processing in lexical access automatically proceeds from the written form of the word *through the speech coding for the word.*

The idea is that activation of the phonological properties of a word is an automatic and integral component in the path of accessing the word's identity in the mental lexicon. Now this has not been as crucial an issue in Japanese psycholinguistic research into lexical access as it has been in Chinese research, largely because Chinese only has the one system of logographic orthography. Japanese has complementary, if not alternative, orthographic systems based on the kana representation of syllable shapes, and therefore this issue has simply never assumed the major proportions in Japanese work that it has in Chinese.

Nevertheless, there has been some work on this issue, and it is useful to report the findings on phonological activation in Japanese. First of all, there has been some work on the small number of Japanese kanji which do have reliable phonetic radicals. Hirose (1992), for example, presented subjects with kanji stimuli, differing in the combinations of left- and right-hand radicals, and had them judge as quickly as possible whether sequentially-presented kanji had the same pronunciation or not. Right-hand radicals played a significant role in phonological processing of kanji, in that kanji pairs which shared the same right-hand radicals exhibited the fastest reaction times. A second experiment employed pairs of kanji which had the same radicals on the left- and right-hand side of the kanji characters, respectively. The left-hand radicals had no facilitating effect on the phonemic processing of kanji, suggesting that the information carried by the right-hand radicals does play some role in the phonological processing of kanji for Japanese readers.

The primacy and number of readings for kanji is obviously a consideration for fluent Japanese readers. Saito and Tsuzuki (1989) investigated retrieval for homophonic bisyllabic kanji in order to establish norms of retrieval variability for kanji readings. Subjects were presented with words transcribed in hiragana and then asked to write as many kanji words as they could think of for that pronunciation within 60 seconds. Correct kanji words tended to be recalled within the first 30 seconds, with a large number of widely differing incorrect kanji words emerging in the last 30 seconds. In the cases of incomplete retrieval, kanji for the first syllable were retrieved three times more often than kanji for the second syllable, reminding one very much of the classic tip-of-the tongue experiments (see Brown and McNeill, 1966,; Kohn, *et al.*, 1987).[6]

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[5] Even so, the pronunciation of many of these phonetic compounds are not identical to their phonetic radicals in Chinese. In Chinese psycholinguistic research, it has been the set of phonographs which have pronunciations which are identical to their phonetic radicals that has served as the focal point of experimentation into lexical access and word recognition.

[6] But the tip-of-the-tongue phenomenon in Japanese, because of the nature of the mixed script system reflects different strategies for storage of lexical items written in kana and kanji. In two experimental probes, Murakami

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However, the use of phonological information may not be as much at issue as is the temporal time frame for interaction between phonological and semantic information in processing kanji. When Wang (1988) asked subjects to find a target kanji word from each of three lists of homographs, homophones, and homonyms, respectively, processing of homographs was the quickest. Processing the other two lists took exactly the same time. A second experiment repeated the same test, using kanji compounds which consisted of four-syllables instead of two, and showed exactly the same results. These results were taken to suggest that phonological and semantic information about kanji are available in a parallel mode rather than a sequential mode.

The effect of homophonic overlap between words is a fairly reliable finding, and that interference effect from homophonic words has been used alone, or in conjunction with various semantic categorization tasks, to test the time course of phonological activation. An early study by Erickson, *et al.* (1977) tested whether silent reading of kanji requires short-term phonetic storage. Four sets of kanji words were prepared as stimuli, with sets phonetically similar, semantically similar, orthographically similar, or neutral, respectively. When subjects were required to write the kanji word which appeared on the screen one second before a probe word, recall of the phonetically similar kanji words was worst among the four stimuli sets, suggesting interference from phonological overlap.

When a semantic categorization task is added to the variable of phonological overlap, the results for Japanese bear considerable similarity to the results that are reported for English. Let us review the results for English first. Van Orden (1987) and Van Orden, *et al.* (1988) gave English-speaking subjects a category name like *flower*, and then had them decide whether a later target word was a member of that category. But they manipulated target words to include targets like *rows*, which is a homophone with a word like *rose*. *Rose* is obviously a real member of the category of *flower*. Both experiments found that subjects made more categorization errors with, and spent more time on, the homophone foils than they did on the spelling controls. What this means is that when the category was *flower* and the target word was *rows*, the existence of homophone foils like *rose* gave more problems than target words which were spelling controls (like *snobs*).

In fact, such homophonic overlap gave rise to problems, even when the target words were non-words. Van Orden, *et al.* (1988) introduced as targets non-words that were homophones. For example, *brane*, was to be matched for possible category inclusion in a category entitled *a part of the human body*. The reasoning is that since non-words such as *brane* are obviously not entries in the mental lexicon, there must be a mandatory phonological activation of such words if categorization errors occur. And indeed, this is just what happens with *brane*, a homophone with *brain*; it does not happen with *blane*, however, a non-word spelling control. What we infer from such results is that there is automatic activation of phonological information in lexical access for English words.

Are there similar results in Japanese kanji processing? Three experiments reported by Wydell, *et al.* (1993) also found a significant homophone effect for Japanese, wherein homophonic target words elicited longer reaction times and more errors than their controls. But Wydell, *et al.* (1993) also found a significant effect which arose from orthographic similarity. That is, incorrect target words that were visually similar to correct examplars, and which fit the semantic category, were also responsible for longer reaction times and higher error rates, although not to the same extent as the results obtained from phonological overlap in homophones. The effects were strongest when both factors intersected, that is, when homophonic targets were also visually similar in orthographic shape to correct exemplars of the semantic category specified. We may infer that, in Japanese, lexical access for kanji invokes both orthographic and phonological representations for the appropriate information.

(1980) presented subjects with ten relatively rare, katakana loanwords, and then with ten kanji compounds. Subjects had to recall the words, recording those segments which they could recall. Retrieval of katakana loanwords was phonologically guided by the syllabic units found in the words, but retrieval processes for kanji compounds suggested that the individual kanji were the units that were being accessed.

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2.2. Semantic Radicals

The traditional belief is that kanji need not invoke phonemic recoding in accessing semantic features, due to the fact that logographs represent words, and not sounds. A single kanji may be complex in that it may include a segment that signals some aspect of meaning or pronunciation, or both. At the left-hand side of the complex character, for example, there may be an additional component that suggests meaning, the radical *hen*. At the right-hand side of the complex character, there may be an additional component which suggests pronunciation, the radical *tsukuri*. Although the positions of these radicals can vary, they generally appear at the left and right sides, respectively. There are some interesting findings for single kanji characters which include more than one of these single components.

There is little question that Japanese readers can often, but do not always, use the cues provided by the component parts of kanji in order to ascertain their meaning. Certainly, kanji components can help readers of Japanese to infer the meaning of unfamiliar technical words in a way that meanings of words transcribed in kana cannot. For example, one experiment matched 30 unfamiliar, technical terms with their definitions; the inferability of the kanji compounds was almost perfect, much like Latin- or Greek-derived technical terms operate for English readers (Hatano, *et al.*, 1981). When subjects were given the 30 definitions and corresponding kana words, and asked to change these into kanji, the correct matchings were also statistically significant; when subjects made correct kanji encodings, they typically inferred correct meanings as well. It appears likely that experienced readers of Japanese have an inventory of kanji building blocks for compound words, especially learned ones, and that using this inventory, in concert with knowledge about compounding schemata, world knowledge, and contextual information, helps Japanese readers to figure out the meanings of unknown words of this type.

There is also a traditional belief that the semantic radicals provide a built-in conceptual categorization system which enhance the semantic search through the mental lexicon. There is little doubt that analysis by 'chunking' of the component parts of a kanji character does take place, and that the semantic radicals are important chunks to be taken into account in this analysis. In some processing tasks, each such radical in kanji is treated as a unit, rather than as an unorganized clutter of strokes. But some kanji are also taken in at a processing glance, so that they are treated as a whole unit, rather than analyzed into their component parts. The evidence for this is mixed, and sometimes semantic radicals offer only vague, and sometimes unreliable, information about semantic groupings in the mental lexicon. Certainly this is the impression one gets from Flores d'Arcais and Saito's (1990) failure to find clear priming effects for semantic components of complex kanji characters. Subjects were presented with a prime word followed by a target word, and asked to name the target word as quickly as possible. If the target word was represented by a component of the prime word, and the meaning of the target word was associated with the meaning of the component, then theoretically subjects should name the target word more quickly than if the prime word did not have as a component the character representing the target word. But there was no significant difference in response when prime and target words were so 'related'.[7]

Flores d'Arcais, *et al.* (1995) contrasted the contributions of the semantic radical (the *hen* component on the left-hand side of complex characters) with the phonetic radical (the *tsukuri*, on the right-hand side) to investigate phonological and semantic activation in Japanese kanji which have these features. Recall that the semantic radical only gives a vague idea of the general semantic field through which a set of kanji characters might be 'semantically' related,

[7] Because Flores d'Arcais and Saito thought that the task might not reveal the effect of semantic priming, they then tried for effects when subjects judged whether word pairs were semantically related. If the two words are unrelated and if one of the two characters contains a component that has a similar meaning to the meaning of the other character, it should take longer to judge words as unrelated, because the presence of the semantically similar components interferes with the production of a negative response. And this is what did happen, namely, negative responses took longer to verify; the implication is that semantic information about components of complex characters is accessed during processing for a semantic judgment task. This, however, may be the case when processing attention is called to such semantic components, but leaves open the question of automaticity and reliability of such information.

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and that the phonetic radical is not a very reliable indicator of pronunciation for most words in Japanese lexicon. Nevertheless, these shortcomings notwithstanding, a pair of experiments manipulated characters that did encode both phonological and semantic information separately in their two radicals. The method was to present such semantic and phonetic radicals with an onset asynchrony, so that either the phonetic or the semantic radical was presented before the whole character. Assuming that both components are activated in the lexical search, this would give a momentary advantage to either the phonological or the semantic information, depending on which radical was presented ahead of the entire character. The results suggest that both phonological and semantic information are activated, since subjects in these two experiments made use of the information as soon as it was supplied. Phonological information seems to become available more effectively in the naming task, adding another processing task to the list of those in which the automatic retrieval of phonological information is activated.

2.3. Compound Kanji

There is a clear correlation between morphological simplicity and frequency of use, in that the simpler a kanji is, the more frequently it is used. But orthographic simplicity vs. orthographic complexity does not necessarily result in processing difficulty. For example, for kanji of 13 strokes or less, difficulty in kanji processing increases proportionally to the number of strokes; however, after this point, increase in the number of strokes actually facilitates kanji processing (see Kaiho, 1979). High frequency kanji are typically easier to read, but when frequency is constant, more complex kanji are easier to read than less complex kanji, because their orthographic complexity in terms of stroke number facilitates their reading (see Kawai, 1966). Subjective judgments of visual complexity in kanji are very sensitive to orthographic attributes like the number of strokes and symmetry in the horizontal, parallel, and diagonal planes. Not only are kanji with fewer strokes considered less complex, so also are symmetrical kanji (see Kashu, *et al.*, 1979).[8]

But this focus on individual kanji does little to illuminate the cognitive procedures employed in dealing with the many common and technical Japanese words which are compounds of two or more kanji. Insofar as compound kanji are concerned, the research suggests that recognition units of kanji are formed on the word level rather than on the level of the individual kanji character. Readings for Japanese kanji are likely computed at the word level, not the individual character level. The phonological rendering of the kanji is highly dependent on the intra-word context, and is finalized at the word level, not at the character level. A series of six experiments by Wydell, *et al.* (1995) confirm that Japanese is different from both English and Chinese in this respect. This result is tied to the fact alluded to earlier, that Japanese can have two types of reading for its kanji, *on* or *kun* readings. And recall, furthermore, that these readings can vary for individual kanji according to the level of intra-word context, and not the individual pieces of the character in respect to phonetic or semantic radicals.

This is further confirmed by Morton, *et al.*'s (1992) experimental inquiry into how single and compound kanji are related within the organization of the Japanese lexicon. They too addressed the question of whether compound kanji are recognized as integrated units or whether their recognition is contingent upon the recognition of their individual kanji components. Two experiments revealed that both single and compound kanji words are facilitated only by pre-training with the identical word, again suggesting that the unit of kanji recognition is a word rather than a character. No facilitation was observed between compound kanji pairs which shared a character, nor was facilitation observed between single and compound kanji words. We must conclude that recognition units of kanji are most often formed on the word level rather than on the level of the individual kanji character.[9]

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[8] Attempts to determine the effect of stimulus exposure time and stimulus complexity on kanji identification also show that complex kanji and symmetrical kanji easier to identify than less complex and asymmetrical kanji under minimal exposure conditions (see Saito, 1986).

[9] This may be related to the fluidity with which compounds appear and disappear in Japanese. This is exemplified in Saito and Kawakami's (1992) examination of where pseudo-compound kanji words might fit into the mental lexicon. Subjects were given 248 kanji compounds and 368 pseudo-compounds, and asked whether

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It may also be that frequency of the two component kanji in a two-kanji compound word has an effect on the path of lexical access. Tamaoka and Hatsuzuka (in press) tested for just such an effect from kanji frequency in both naming and lexical decision tasks. A first experiment on naming created 80 two-kanji compounds by controlling frequency (high vs. low) and position (left-hand vs. right-hand character in the compound). The results revealed that high frequency kanji in the left position facilitated accuracy and speed in the naming responses. Of course, since naming initiates phonological activation, the frequency of the left-hand character will inevitably affect naming. A second experiment on lexical decision augmented the above stimuli with the same number of pseudo-homophonic compounds, whereby one of the compounding elements in a given kanji was replaced with a homophonic kanji. Subjects were then asked to judge as quickly and accurately as possible whether the stimulus compound was a legitimate kanji compound or not. In this case, high kanji frequency in the right position facilitated accuracy and speed in the lexical decision task. Because the lexical decision task cannot be realized without processing the right-hand kanji, the frequency of the right-hand kanji shows an effect.

Through a lexical decision task, Hirose's (1992) three priming experiments also seem to have found some support for the role of the first kanji in the storage and retrieval of kanji compounds in memory. A first experiment tested for the features used to retrieve compound words from memory, and found that the initial character in kanji compounds primes kanji compounds. A second experiment tested the effect of kanji primes which differed in pronunciation, but were identical to the initial kanji in the compound to be activated; there was no significant effect attributable to difference in pronunciation, suggesting that it is the meaning associated with a character that is activated in the retrieval process. The third experiment manipulated kanji primes in respect to their frequency of occurrence as elements in kanji compounds; low frequency primes showed a greater priming effect than high frequency kanji, suggesting that compounds which share an initial kanji are clustered together in the mental lexicon, according to the meaning of the first kanji in the compound word.

Frequency also interacts with the kind of morpheme represented by the kanji. Not all kanji are created equal, so to speak! Some kanji fall into the category of bound morphemes, and can only be used in that context, much are as derivational Latinate prefixes in English are limited in occurrence. Yamada (1994) tested their status by employing a naming latency task to contrast two views of kanji recognition and naming the post-lexical access hypothesis (i.e., meaning-to-sound) and the competition or horse-race hypothesis (i.e., competition between the phonological and semantic routes). Thirty subjects were given an audiovisual tachistoscopic task in which they had name as quickly as possible the following three types of kanji (i) single bound morpheme kanji, lacking a specific meaning when not part of a compound word; (ii) kanji compound words, containing the bound morpheme kanji as the initial compounding element; and (iii) possible kanji compound words which could be generated from the bound morpheme given. Subjects took longer to name the kanji compound words from which only the initial bound morpheme kanji was given than to name the single bound morpheme kanji. The author therefore favors competition over post-lexical access explanations because such single bound-morpheme kanji are generally named by directly accessing the phonological level instead of directly accessing the lexical level. But the point, insofar as our discussion is concerned, has to do with the variable status that kanji have. Not all kanji should be considered to have the same function or access path in the architecture of kanji storage in the Japanese mental lexicon.

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they knew the compounds and whether they could be found in the dictionary. Two-thirds of the subjects judged that approximately 20% of the pseudo-compounds could be found in the dictionary, suggesting that readers differentiate pseudo-compounds from kanji compounds not so much on actual lexical addresses as on their lexical likelihood. However, to be able to access the actual lexical address one must know the compound as an existing compound word, with its own unique configuration of phonological and semantic attributes.

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3. KANA

There are two syllabary types in Japanese, the katakana syllabary and the hiragana syllabary. The katakana syllabary is more angular in the shape of its symbols, and is commonly declared as the appropriate transliteration medium for loan words into Japanese from other languages. However, it sees a good deal of use in modern printed Japanese as a kind of visual italics, useful for highlighting exclamations in literature and comic strips, neologisms, and useful in advertisements which call attention to brand names or brand qualities. Hiragana, on the other hand, is more cursive in its symbols, and its shapes are more easily discriminated one from the other. Although it can be and is used for writing some content words, it is commonly used in writing the non-content words and grammatical morphemes not usually presented by kanji characters; in short, it is used for morphological endings, function words, and the rest of the grammatical scaffolding of Japanese sentences.[10]

Although Japanese research has concentrated more on the possible processing differences between its two orthographic types, syllabary vs. kanji, some work has also attended to possible processing differences between its two syllabary types, hiragana vs. katakana. Some have taken this to mean that the two syllabaries are domain-specific, with the main function of katakana tied to its representational function for foreign loan words. Hatta, *et al.* (1984), for example, contrasted lexical decision rates for English-speaking learners of Japanese with native Japanese speakers, in order to tease out the nature of lexical representation for loan words in Japanese. They suggest that native Japanese readers possess two separate, but partially overlapping lexicons: a foreign word lexicon to which katakana corresponds and a Japanese word lexicon to which hiragana script corresponds. In contrast, they claim that native English learners possess only one lexicon, a Japanese word lexicon, to which both hiragana and katakana correspond.

However, Hatta and Ogawa's (1983) experimental results seem to suggest otherwise for Japanese subjects themselves. They tested whether significant repetition effects occurred for the two kana types; if not, the two kana representational types can be considered similar. Significant differences were found, however, and the two types are to some extent distinct. Hiragana and katakana did not completely overlap for their Japanese subjects, but did share some representational features. And so they should, for they can be used to represent the same word, although typically a word will appear in one or the other script.

This fact of ultimately accessing the same lexical address is seen in Komatsu and Naito's (1992) three experimental tests of repetition priming with kana in word-fragment completion. They manipulated katakana and hiragana to determine the effects of a script change between study and test on later word-fragment completion. Stimuli consisted of foreign loan nouns which would normally be written in katakana, but not hiragana. Such manipulations allow exploration of explanations based on imaging strategies to the phenomena of cross-script, cross-modal, and conceptual priming. The results revealed reliable cross-script priming between katakana and hiragana, as well as substantial cross-modal priming when the presentation modality was changed from auditory to visual. Ultimately, word recognition will take place, but there is no question that the path to word recognition will be facilitated by the fact of script familiarity for either katakana or hiragana presentations. At some level, these are seen as alternate paths to the same lexical address. Hirose (1985) also found evidence of this effect in a two-trial lexical decision task in which subjects were first asked to decide if words appearing on a screen were legitimate words or not. Two types of stimuli written in katakana were prepared Japanese words whose normal orthographic representation is in hiragana; and loanwords, whose normal representation is in katakana. A second trial differed from the first

[10] Kana has never replaced kanji completely for a variety of reasons. A common argument is that Japanese has too many homophones, words with the same pronunciation whose differing meanings are efficiently shown by their having different kanji characters. For example, in discussing design problems associated with Japanese keyboard input, Yamada (1983) cites a vocabulary count of one popular Japanese dictionary as showing 36.4% of the entries to be homophones. The flip side of this classic argument is that spoken Japanese seems to flow effectively without visual support of the kind claimed as necessary through kanji. Correct interpretations are, for the most part, immediately and accurately assigned simply on the basis of discourse and contextual cues.

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in that half of the stimuli differed from those in the first trial. Not surprisingly, in the first trial the Japanese words written in katakana were processed slower and less accurately than the loanwords. However, in the second trial the Japanese words were processed faster and more accurately than in the first trial, showing a clear facilitation effect. No such facilitation effect was observed for the loanwords, suggesting that this facilitation effect in familiarization must have taken place at the level of visual processing in the first trial.

The primacy of katakana for loanwords is also questioned for by two experiments which examined the effect of orthographic familiarity on recalling English loanwords (see Yokoyama, 1991). A first experiment had undergraduates read aloud each of 72 words appearing on a screen. These stimuli, classified into high vs. low imagery words, were written both in katakana (the typical orthographic form for loanwords) and hiragana (an atypical way of representing loanwords). The subjects' task was then to recall as many words as possible in a 60-second period, and although high imagery words were better recalled than low imagery words, there was no significant orthographic effect. A second experiment had another group of undergraduates perform the same task, but also had them engage in a mathematical task for 30 seconds before recalling the words. The result was that high vs. low imagery had no effect on recall, but there was now a significant orthographic effect. Orthographically unfamiliar hiragana words were now recalled better than orthographically familiar katakana words, perhaps because of the cognitive effort required to read the orthographically unfamiliar words. As for the findings with non-native learners of Japanese, the results are colored by the fact that katakana representations are invariably more difficult for non-native learners of Japanese. The graphic distinctiveness of hiragana is typically easier for foreign learners to use in discriminating Japanese words, whereas the graphic overlap of the angular katakana is often a source of processing difficulty. This is borne out in Hatta and Hirose's (1984) pair of experiments testing whether foreign learners of Japanese differ from Japanese in processing kana words. A first experiment presented 200 Japanese words and English loanwords to 26 Japanese native speakers, while the second experiment presented them to 14 Australian students of Japanese with an average of 4.2 years of study behind them. Both Japanese words and English loanwords were processed faster by Japanese subjects when these words were presented in their conventional kana types (i.e., hiragana for Japanese words and katakana for loanwords). Hiragana facilitated processing for the Australian subjects, while katakana failed to do so.

The very fact that kana is used to transcribe real words gives it an informational value, much as grammaticality contributes to the recognition and recall of sentence-like strings. For example, Miura (1978) found a word superiority effect for hiragana strings when testing for the effect of syllabification by tachistoscope. Orthographic regularity and meaningfulness in respect to symbolization of real words may be important determinants of the word superiority effect, but kana unitization which depends upon syllable-like structures is not.

Some authors even suggest that the nature of the resulting phonological representations may be different for scripts based on alphabets and syllabaries. Both kana orthographies are based on the syllabic structure of Japanese, and are thus converted into phonology, but Besner (1990) claims that the phonology derived from reading syllabic Japanese kana script is more closely tied to articulatory activity than is the phonology derived from reading the alphabetic English orthography. But Tamaoka and Taft (1994) found that the smallest unit of phonological processing in Japanese is the phonemic segment, not the mora which is orthographically represented by kana. They modified katakana words for a lexical decision task in which words like *ka-me-ra* 'camera' could appear in three different ways the vowel of the initial mora was altered, giving *ko-me-ra*; both vowel and consonant of the initial mora were altered, giving *so-me-ra*; or two initial morae were altered, giving *so-ki-ra*. Subjects were presented with 30 stimuli sets on a videoscreen and asked to decide whether the stimulus was a word or not. Longer response times were required for *ko-me-ra*, suggesting that subjects only accessed lexical information for the first type. Although the mora is the smallest unit of orthographical representation, Japanese subjects were sensitive to phonemic segments in processing these kana words, suggesting that phonemic segments are the smallest unit of phonological

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processing. Although the hiragana and katakana syllabaries of 48 symbols represent the same inventory of 111 syllable shapes in Japanese,[11] they do not completely overlap.

External factors such as script familiarity exert an influence on lexical decision tasks. Reaction times increase in proportion to word length for unfamiliar script words, that is, in inverse proportion to the frequency with which a given word is normally seen in either katakana or hiragana script. Conversely, this increase is not found with familiar script words. And we shall say more about this phenomenon, and other processing differences between the two syllabary types, in the following sections.

4. KATAKANA

Orthographic attributes contribute to making kana letters hard or easy to read. A lack of distinctiveness, and similarity between kana shapes, interferes with legibility for both hiragana and katakana. When two hundred junior high students were asked to cross out specified symbols from sets of katakana and hiragana as quickly and as accurately as possible. Simplicity and less curviness contributed to hiragana legibility, while simplicity and the presence of a horizontal or parallel line (vs. the absence of a diagonal line) contributed to katakana legibility (Matsubara and Kobayashi, 1966). But katakana appear to pose a greater processing burden than hiragana, possibly because of their lack of discriminability owing to graphic overlap.

This is borne by work on the effect of letter sizes on haptic recognition. Three different letter sizes (3.0x3.0, 5.5x5.5, and 8.0x8.0 mm.) for the 26 alphabetic letters and 48 katakana were presented to subjects charged with alphabet recognition and katakana recognition, respectively. Accuracy increased as size increased for both alphabet and katakana, but katakana recognition was worse than alphabetic (Tasaki, 1992). Yokoyama and Yoneda (1995) found no significant decrease in recognition rate for kanji when noise levels were introduced, but there was a linear decrease for kana, with katakana recognition rates under noise conditions worse than hiragana. Kaiho's (1968) multiple regression analysis charts the factors which affect katakana legibility. Frequency of katakana have no positive effect on katakana legibility under noise conditions, but orthographic features do have a positive effect on legibility. For example, the salient factors which emerge are horizontal and longitudinal directionality and redundancy.

The Semantic Differential has also been used to show how orthographic type affect subjective evaluation of script appropriateness. Common words like *chair* and *watch* were presented in kanji, hiragana, and katakana to 85 undergraduates, who evaluated them on a seven-point SD scale. Script effects were obvious, with the angular scripts inherent in kanji and katakana factoring out separately from the more cursive hiragana, possibly owing to the historical derivation of katakana from kanji, with hiragana arising from different origins (see Sugishima and Kashu, 1992).

4.1. Familiar Katakana Words

The received view on lexical access for Japanese words was at first that words written in kana necessarily rely on their phonological values for lexical access. In contrast, words written in kanji, it was thought, would be accessed directly from their visual image. But visually familiar sequences of kana, particularly common katakana words, are often treated as chunks in reading, in a way that visually unfamiliar sequences are not. This means that kanji are not the only forms that, theoretically at least, can be accessed directly from their orthographic image. Besner and Hildebrandt (1987) offer some interesting evidence on whether lexical access for words written in katakana can be achieved without reference to phonological recoding. Katakana words were presented in three ways visually familiar words usually written in katakana, visually unfamiliar words usually written in kanji, and non-words. Japanese

[11] According to the Nihongo Hyakka Daijiten, the generally accepted number of syllable shapes in Japanese comes to 111 in number.

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subjects read the stimulus words aloud as rapidly as possible, and naming latencies were recorded. Visually and orthographically familiar words were named faster than both visually unfamiliar words and non-words, suggesting that such kana words have a more direct lexical access. This shows up as an advantage in oral reading over those kana words that must resort to sound-spelling correspondence rules, and one infers that lexical access for some familiar words printed in katakana can be achieved without recourse to the preliminary steps involved in phonological recoding.

The effects of script frequency on word recognition may be noticeable for words written in katakana, because of their special visual status as 'one of a kind'. Tanaka and Konishi (1990) contrasted both words and non-words, presented in four different orthographic conditions high frequency katakana words; high frequency kanji words; low frequency katakana words, usually written in kanji; and low frequency hiragana words, usually written in kanji. The words were presented to both the left and right visual fields of 10 adult subjects, who had to discern as quickly as possible non-words from words. In another session, they also sorted the words into semantic categories. As expected, there was a clear frequency effect separating high and low frequency katakana words, with high frequency words processed faster than their low frequency counterparts. But there was also a visual field difference; the low frequency words showed the involvement of the right visual field, whereas the high frequency katakana words did not. Lastly, there was a word-length effect for low frequency words; the longer the word, the slower the processing time. One might infer that low frequency katakana words require phonemic processing, whereas high frequency katakana words allow direct access to their meaning.

5. HIRAGANA

Although the effects of script frequency on word recognition are experimentally supported for words written in katakana, the same must be true for those many non-content words of the grammatical morpheme type that are typically written in hiragana. However, most of the work on script familiarity focusses on the typicality of the two syllabary types, and not much work focusses on hiragana itself.

5.1. The Issue of Script Familiarity for Kana

Script familiarity will invariably exert an influence on lexical decision tasks, such that orthographic familiarity of kana strings is a major variable in lexical access procedures. Kawakami (1993) examined this by using familiar/unfamiliar words, three to five kana in length, which were half-written in the kana script they are not usually written in. Subjects judged whether these stimuli words, some of which were misspelled, were real words. Reaction times increased in proportion to word length for unfamiliar script words, but this increase was not found with familiar script words. A second experiment had subjects again making lexical decisions, but reading from right to left instead of in the usual order. This unusual reading condition increased reaction times for both familiar/unfamiliar script words in direct proportion to word length. We may infer that visually familiar sequences of kana are treated as chunks in reading, in a way that visually unfamiliar sequences are not. Similarly, Sasanuma, *et al.* (1988) conclude that orthographically familiar kana words have direct access to the lexicon on the basis of the orthographic code, while orthographically unfamiliar words require recourse to phonological recoding. Their conclusion is based on reaction time differences in lexical access procedures for different types of kana strings. Orthographically familiar *kana words* (words which are normally written in kana) were contrasted with non-words and *words in kana* (words which are not normally written in kana, as for example, kanji transcribed into kana or katakana loan words transcribed into hiragana). Response times for orthographically familiar words were significantly faster than for non-words, and often faster for orthographically unfamiliar words.

Yamada, *et al.* (1990) tested for the effect of variables such as lexicality (words vs. non-words), kana type (hiragana vs. katakana), string length (long vs. short), and vocal

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interference (silence vs. concurrent vocalization). The results show that the more conventional strings are, the more quickly they are recognized, thus substantiating the generality of conventionality and lexicality effects in reading symbol strings in various orthographies. They conclude that a visual orthographic lexicon for kana reading exists in normal adult Japanese, such that many higher frequency words are recognized on a visual orthographic basis and lower frequency words on a phonologically analytic basis. But subjects did divide into two groups, orthographic lexicon users and phonological assemblers, differing in the size of their respective sight vocabularies, but both employing sight vocabularies. These results point to the involvement of both an orthographic route and phonological assembly route which is consonant with the dual-route hypothesis. It certainly contradicts the common view that kana words must be accessed through phonological mediation alone.

6. KANA SCRIPT VS. KANJI SCRIPT PROCESSING

Are there processing differences between kana and kanji script types? Are words written in kana named faster than the same words written in kanji? Are there hemispheric differences in laterality preferences that are associated with kana processing vs. kanji processing?

Japanese speakers are certainly prepared to make subjective judgments of appropriateness of script type for everyday words. One experiment had 219 undergraduates choose the script type they considered as the best fit for each of the 119 common words, such as *glasses* and *box*. A second experiment had 193 undergraduates judge whether a given script type was appropriate for each of the 119 words. Both experiments revealed consistency in subjects' judgments, with almost half of the words deemed to be best as kanji (see Ukita, *et al.*, 1991).

Early views projected processing differences between kanji-reading and kana-reading, and held that kana would generally take less time to read than kanji. But kana reading speed was said to slow down as the number of kana increased, while the number of kanji did not affect reading speed for kanji (Saito, 1982). The notion, of course, was that kana require phonemic intervention to access to their semantic referents, but that kanji would directly access their semantic referents (see Saito, 1981). But kanji research revealed that even purely graphemic tasks evoke phonemic processing of the lexical unit involved, suggesting that kanji and kana both involve graphemic, phonemic, and semantic processes. The main difference in reading kanji and kana, however, was then postulated as involving differing processing routines, differing in the way that the path to lexical access was realized. Specifically, kana would invoke graphemic, phonemic, and then semantic processing, while kanji would invoke graphemic, semantic, and then phonemic processing (Saito, 1982).

Feldman and Turvey (1980) did find some evidence for the speed of kana processing. They tested the relationship of orthographic type in Japanese to the availability of phonological information by comparing latency differences in naming kanji and kana words. It was hypothesized that naming words written in kana exploits both an orthographic strategy (based on letter-sound correspondences) and a word-specific strategy (based on visual shape); naming words written in kanji only allows the latter because kanji have no phonological properties. Six color names were written in both scripts and presented to two Japanese subjects, who were instructed to read the stimulus words as rapidly as possible. On the one hand, one might expect that word frequency and visual scanning efficiency would predict shorter naming latencies for kanji than for kana, because color names appear more frequently in kanji and with compact graphic patterns. On the other hand, the phonologically-based nature of kana would suggest an advantage for kana in vocalization. The results show that the response latencies were consistently faster for kana, suggesting that the phonologically-based orthographic form of kana accounts for greater facility in naming.

But these findings must be tempered by the results of three experiments on the effect of syllable length in kana and kanji word recognition. These results revealed that the number of syllables in kana words affected recognition times, but this was not true for words which consisted of a single kanji. Recognition times were affected, however, by the number of syllables in words which consisted of two kanji and were typically longer (Tada, 1975). And script frequency for

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kanji and kana words also exerts its effect on processing speed. Hirose (1984) examined the effect of script type and frequency on lexical access by having undergraduates classify words into semantic types. Script type and frequency were manipulated to form three groups words written in kana though their regular script type is kanji (low-frequency kana words); words written in kana just as they are usually represented (high-frequency kana words); and words written in kanji (kanji-words). Findings were that the low-frequency kana words took longer to process than the kanji words; however, there was no difference between the high-frequency kana words and kanji words in processing time. We may infer that the type of orthography per se does not affect processing time; rather it is familiarity with the frequency of the orthographical shape which has an effect on lexical access.

Kanji, hiragana, and katakana recognition is differentially affected by noise levels. When these three script types were filtered through three levels of visual noise (15%, 20%, and 25%), Kanji was better recognized than kana at all noise levels for both humans and an Optical Character Reader. There was no significant decrease in recognition rate for kanji as the noise level increased, but there was a linear decrease for kana, with katakana worse than hiragana. Yokoyama and Yoneda (1995) attribute the robustness of kanji recognition to iconicity and the distinctive number of strokes involved (see also Yokoyama, 1995).

Most studies of kana and kanji focus on reading differences between the two scripts, but other areas in kana and kanji research have also elicited experimental attention. For example, script frequency affects not only reading, but also affects recall of kana and kanji words. One experiment reports using three types of words as stimuli in both reading aloud and incidental recall tasks for 44 undergraduate subjects words which are regularly written in kana (kana-type); words which are regularly written in kanji (kanji-type); and words which are regularly written either way (kana/kanji type). In the reading aloud task, the reading of the kanji- and kana/kanji-type words which were represented in kanji was as fast as the same types of words represented in kana, indicating that the kana (i.e., phonological) mode of representation itself does not necessarily enhance reading speed. In the recall task, recall for kana-type words which were represented in kana were as good as those represented in kanji, indicating that the kanji (i.e., semantic) mode of representation itself does not necessarily enhance recall speed (see Sugishima, *et al.*, 1993).
Imagery also has an impact on recall and memory. In another experiment, subjects were unexpectedly asked to recall kana and kanji words which had been ranked in terms of high vs. low imagery. Imagery had an impact on the recall of kanji words, but a variable impact on recall for kana words, illustrating the significance of orthographic types on recall and memory (Yokoyama, 1995).

7. MIXED KANA-KANJI TEXTS

But the basic fact of everyday printed Japanese is that phonetic and non-phonetic script are intermingled in ordinary text to be read. And so one must be careful to discriminate between those models of word recognition and the mental lexicon which pose explanations through autonomous vs. interactive models such explanations differ crucially in their treatment of contextual effects on lexical access; the autonomous model denies contextual effects, whereas the interactive model depends upon them. We know from previous work on lexical ambiguity, that resolution is tied to the final processing stage, and that at a very early stage of processing homophones at least, multiple readings unaffected by context are considered. This initial stage is immediately replaced by the selective reading which fits the contextual restrictions (see Kess and Hoppe, 1981; Kess and Nishimitsu, 1990; Kess, 1992). We may have to adopt a compromise model which specifies at which temporal course of information processing lexical access is autonomous or interactive (see Yi, 1987).

In the normal course of events, printed Japanese typically intersperses kanji and kana in printed sentences. When one considers normally integrated syllabary-logograph texts, reading times are faster for the mixed kana-kanji script type than for the kana-alone type. The number of compound kanji does exert an influence, however, so that nursery tales are read faster than scientific essays. Highly specific content words, like technical or scientific terms, tend to be

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learned as kanji at their first appearance, and these words are commonly written in kanji at all stages in the education system. When one compares hiragana-only texts with mixed-hiragana/kanji texts, mixed texts are processed faster than the hiragana-only texts. Eye-voice span, the difference between eye-movements and actual vocalization, reveals no difference between the two types of text, however. When Kitao (1960) then had subjects fill blanks with appropriate words in a cloze test, mixed texts facilitated more accurate responses than hiragana-only texts. Mixed texts are not only are easier to read than kana-only texts, but they seem to facilitate the extraction of meaning from the text as well.

There are also differences in how the concurrent vocal interference effect plays out in reading comprehension. Hayashi and Hayashi (1991) measured reading comprehension for kana and mixed kana/kanji sentences in the presence of concurrent vocal interference.[12] Script types for sentences were either mixed kana-kanji or kana alone in eight stories whose contents were either scientific essays or nursery tales. Mean reading times were computed for each condition and taken as an estimate of the relative difficulty of reading a given sentence under the various conditions. Reading times were found to be faster for the mixed kana-kanji script type than for the kana alone type, and nursery tales were faster than scientific essays. Intersentential comprehension of the scientific essay was negatively affected by the concurrent vocalization task, especially when written in the kana alone script type. General or basic content words, such as those in the nursery tales, may have been experienced in both the kana and kanji scripts, while specific content words tend to be learned as kanji at their first appearance, and it is more natural for these words to be written in kanji at all stages in the education system. These facts must also be taken into account when reviewing the findings regarding discourse type.

Kimura (1984) had subjects judge whether pairs of words written in kana or kanji were related in meaning, but under conditions of concurrent vocal interference. The results revealed that concurrent vocal interference impaired performance for kana words but not for kanji words, suggesting that vocal interference disrupts prelexical phonological coding in the kana script. A more recent study by Kinoshita and Saito (1992) finds somewhat different results in their attempt to determine whether concurrent articulation of irrelevant material disrupts the interpretation of words presented in kanji and kana. The authors assumed that words written in kanji are interpreted visually by the internal lexicon, while words that are usually written in kanji but are presented in kana must be interpreted by determining the sounds corresponding to each symbol. They thus predicted that concurrent articulation would disrupt the interpretation of kana-transcribed words more than kanji words. Subjects were presented with word pairs that differed in pronunciation by only one syllable and were asked to decide if the words had the same vowel in this syllable. Four conditions manipulated the script (words were presented either both in kanji, or one in hiragana and the other in katakana) with the presence or absence of concurrent articulation. Concurrent articulation interfered most with the interpretation of kanji words, but this surprising result was explained when the researchers discovered that subjects had judged the kana words by comparing orthographic symbols until a mismatch was found. The authors suggest that when the task is performed in this manner, one would expect concurrent articulation to be more disruptive for the kanji words. A second study using the same design had subjects judge whether word pairs were homophones. The results again indicated that concurrent articulation interferes more with judgments of kanji words than of kana-transcribed words. A third study had subjects judge kanji and kana-transcribed strings as words or non-words, either with or without concurrent articulation. The results indicate that concurrent articulation had no significant effect on the lexical decision task for words presented in either script. These authors conclude that concurrent articulation does not hinder prelexical phonological recoding.

When one takes the variable of vocal interference into children's processing of kanji and kana, one begins to suspect that metalinguistic differences also enter the picture. Tamaoka, *et al.* (1992) classified 108 elementary school students from grades 4-6 as skilled and less skilled

[12] Concurrent vocal interference involves subjects repeating irrelevant material aloud while reading of making judgments and is thought to disrupt the auditory/articulatory channels because it interferes with the phonological code but leaves the visual code unaffected.

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readers, and had them judge sentences as being semantically correct or incorrect. Embedded in each sentence was a commonly-used word, usually written in kanji, but now presented in hiragana or the normal kanji. Two treatment conditions involved either no interference or vocal interference, which was created by having subjects count repeatedly in Japanese from one to ten while performing the task. The results show that even though words in kanji were processed faster than words in hiragana, vocal interference had a similar effect on the processing of both scripts. And interference impaired less skilled readers more than skilled readers and younger children more than older children. A second study using a similar methodology had the same students judge the semantic correctness of sentences containing a commonly-used word, usually written in katakana, but now presented in hiragana or the normal katakana. Again, the authors found that vocal interference inhibited less skilled readers more than skilled readers and younger children more than older children, suggesting that age, reading ability, and metalinguistic difference affect lexical access for children.

8. ROMAJI

Not a great deal has been done with the alphabetic script called *romaji*, so called because the Japanese use of 22 of the 26 letters of the alphabet is based on the Roman, or Latin, alphabet. Discussions of literacy and word recognition in Japanese research is usually limited to the three scripts we have just reviewed.[13] But the romaji script has made such inroads into popular Japanese printed media that it must be accounted for a separate system within the Japanese orthographic inventory. Romaji is common in road signage and media advertising, as well as in everyday journalese and even colloquial conversations; for example, consider *OB*; *OL* 'old boys', as in 'old boys' network'; 'office ladies or office girls'. It does not matter whether abbreviated company names are Japanese (KDD=*Kokusai Denshin Denwa* 'International Telegraph and Telephone' or English (NTT=*Nippon Telephone and Telegraph*. It has become indispensable for designating certain commercial layouts, sizes, or conventions. Consider the standard format for real estate ads exemplified by *3DK*, meaning '3 rooms, plus dining room and kitchen', or the L, M, S sizing for *T-shatsu* 'T-shirts' or *V-nekku suetaa* 'V-neck sweaters'.

According to Saint-Jacques (1987), the increase in romaji is exponential, and the cumulative effect such romaji is increasingly perceived as a standard form of writing. It certainly can no longer be regarded as an alien form of writing, exotic and incomprehensible to the average Japanese. Words from English, French, German, and other languages that only a few years ago were written in katakana are now often imported and written in the original Roman alphabet. Even some Japanese words and proper names have begun to appear in romaji, even in the middle of a normal Japanese sentence. Aside from the advertising panache attached to foreign imports, the reason is simple. A romaji word will stand out from the rest of the script presentation, simply because it is so different.

Romaji has also become the vehicle by which computer keyboards access the other three Japanese scripts in word processing and dictionary software packages. Inevitably, a more efficient system had to replace the traditional 'hunt-and-peck' method of sorting through the 3,000 base characters in Japanese typewriting and typesetting, and romaji provides the key to unlock the ergonomic puzzle to entering input simply and conveniently (see Yamada, 1983). It is not a pedagogical subject in the same way that the kana syllabaries are, but the romaji chart is introduced as early as Grade 4 textbooks. Nevertheless, some educators see this as a disadvantage rather than a bonus. The argument is that romaji hinders rather facilitates the acquisition of English vocabulary because the gap between English words such as *table*, *computer* and Japanese borrowings like *teeburu*, *konpyutaa* is simply too large to be anything but confusing. There is, however, experimental evidence to show that knowledge of romaji is linked to the ability to read English words (see Yamada, *et al.*, 1988).

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[13] Through English, Arabic numerals have also appeared to take the place of kanji numerals in most horizontal writing.

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9. CONCLUSION

Japanese research into the processing dimensions of a mixed orthography sheds light on the basic questions of word recognition and lexical access research in psycholinguistics. Our purpose in this paper has been to introduce this rich psycholinguistic paradigm, and to show how which considerations affect the path by which lexical access becomes word recognition in processing written Japanese when presented in exclusively syllabary, Chinese kanji characters, or mixed scripts. The picture for Japanese lexical access is obviously not a simple one, but it is certainly an interesting one because of the complexity of the writing system. Certainly the picture is not so clear as to allow us to choose between one simple, thorough-going explanation which places logographic scripts on one side and alphabetic scripts on the other. It is obvious that the mental lexicon has a complex structure which allows some complex kanji to be retrieved either phonetically or semantically, enabling Japanese readers to figure out the meanings of unknown words by using the kanji lexicon in concert with compounding schemata, world knowledge, and contextual information. A better way of looking at the problem might be to suggest that kanji processing can employ either of two processing routes in accessing the specific properties of a lexical item presented in kanji script. In fact, this notion of a double-route is not limited to logographic systems using hanji or kanji, but it can apply to access strategies in alphabetic or syllabic systems which are phonologically based.

We are not, however, saying that kanji processing is the same as alphabetic or syllabary processing, especially in the earliest stage of processing. It seems reasonable to assume that pattern recognition processes are likely to be different for stimuli of the logographic type and stimuli of the alphabetic or syllabary type, with logographic stimuli having a greater dependence on visual pattern-matching stimuli. And, of course, there is a vast array of experimental literature using a variety of experimental tasks which suggests a contributory role of graphemic information (see Miyamoto and Kess, 1995; Kess and Miyamoto, 1994; Kess and Miyamoto, 1996).

But, by the same token, we cannot support the equally simplistic view that kanji processing has a single route, with a cognitive leap from Orthography to Semantics which ignores the contribution of Phonological information. The most plausible cognitive model may mix its basic tenets in this respect. That is, depending upon the contextual setting for a given kanji, and its specific features of familiarity, frequency, and complexity, one of two processing routes may be taken. Both processing routes ultimately access semantic information, but one route is a sound-mediated route and the other route is a grapheme-mediated route. For many processing tasks that involve natural language, kanji symbols are like alphabet or syllabary symbols in that they must invoke phonological properties as the decoder searches through the mental lexicon. Tasks that are not simple pattern-matching maneuvers take the decoder from Grapheme through Phonology to Semantics. We suggest that phonological properties are automatically accessed in most analytical tasks that are not pattern-matching or category-matching in nature.

We also suggest that there is a cognitive routing that can travel a grapheme-mediated route. This is the only way that we can account for how some tasks access information about, as well as make decisions on, kanji logographs that do not require phonological mediation. Moreover, Japanese kanji and Chinese hanji will employ a direct route especially in cases where hanji exhibit high frequency and high familiarity. There are, of course, examples in alphabetic systems like English where the processing route travelled is a direct route. For example, the English lack of a perfectly transparent sound-letter correspondence is overlooked in cases of morphophonemic identity such as the plural <-s>, the past tense <-ed>, the alternation /haws > hawz-/ in *houses*, and so forth. This is certainly the case in repeated instances of highly idiosyncratic spellings; these quickly become immune to phonological analysis and their spellings are soon ignored. Words like *Ubyssey* in British Columbia, *Liliuokalani* in Hawaii, *Thames, Gloucester*, and *the admirable Crichton* in Great Britain, and well as common words like *thyme*, are forms of this type. There is, of course, considerable experimental support for this. For example, in two experiments using a vocalization task, Seidenberg (1985) has shown that very frequent words in English are recognized visually, without phonological decoding, just as they are in Japanese and Chinese. Infrequent or newly-coined words were accessed by

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referring them to the process of phonological decoding, whereas high frequency words and characters were recognized visually without phonological mediation.[14]

Thus, it may not be an all-or-none hypothesis we should entertain in our explanatory model. A number of critical factors enter into the question of what will be the most efficient strategy for achieving the task at hand, If this expectation is valid, then we surmise that the claims for the absolute uniqueness of logographic systems of Japanese kanji and Chinese hanji are considerably weakened. The grapheme-mediated primary route would be unique to neither Chinese nor Japanese, but is a matter of degree, tied to how often this route is activated as the primary route. Such a dual route notion, with its suggestion of two possible routes to lexical representation, one a phonological route and the other a direct route, is congruent with experimental results arising from work on lexical access, word recognition, and reading in other languages.

Although the current philosophy of science inexorably draws our attention to the question of universal constraints on how the mental lexicon is searched, language-specific considerations of correspondence regularity, frequency, and familiarity exert an influence as well. Holding these factors constant, the analytical task type may drive the choice of the most efficient route for turning lexical access into word recognition. The three types of orthography, alphabetic, syllabic, and logographic, certainly differ in their representational basis, in being either phonologically based or morphologically based in principle. But they will not be inherently different in their processing nature, in that graphemic properties and phonological properties will be both processed, but to varying degrees in different tasks. For example, it is obvious that search procedures treat kana as more than strings to be phonologically recoded. Orthographically familiar words in kana script are named faster than both visually unfamiliar words and non-words, suggesting that such words bypass the orthographic code to direct lexical access. Thus, it is not the type of orthography that determines processing time; rather it is familiarity with the frequency of the orthographical shape which has an effect on lexical access. We must conclude that the degree to which we employ the two processing routes may differ across languages, but the fact of their availability will not vary across these languages.

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[14] For Seidenberg's Chinese subjects, phonetic compounds were read more quickly than non-phonetic compounds when the characters were of a low frequency. In Seidenberg's experimental results, the interactive relationship of Chinese hanji compounds with low frequency may have exploited phonetic activation as the most effective processing strategy. This is also what Leong, Cheng, and Mulcahy (1987) conclude after analyses of variance underscored the individual contributions of reader ability, frequency of hanji, and complexity of the hanji to vocalization latencies in reading Chinese lexical items.

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