Word comprehension and naming: An analysis of English and Japanese orthographies

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A Japanese version of the Stroop test was used to study interference effects produced by conflicting color words written in Kanji, a logographic orthography, and in Kana, a phonetic orthography. Words written in Kanji produced more Stroop interference than words written in Kana, even though words written in Kana were named faster. In another experiment, English readers indicated the spatial location of stimuli in the presence of conflicting arrows or words (e.g., the word left in the right position). Conflicting arrows (i.e., logographic symbols) produced more interference than conflicting words, yet words were named faster. In a Japanese version of the same task, subjects experienced the most difficulty when conflicting Kanji words were presented. But again, words written in Kana were named faster than words written in Kanji. Thus for both Japanese and English readers, logographic symbols were identified faster than phonetic symbols, yet phonetic symbols were named faster than logographic symbols. The findings demonstrate that by varying orthography, it is possible to dissociate word comprehension from word naming.

Reading depends upon our ability to assign meaning to visual symbols. Readers of Western languages are familiar with phonetic orthographies in which visual symbols represent the basic sound units that combine to make up the spoken language. An alternative possibility is to make each symbol represent a unit of meaning. Writing systems that use symbol-meaning correspondences are called logographic. Written Chinese, which is used by more than half of the world’s population, approximates a logographic orthography. Most other languages, including English, are predominantly phonetic but do use logographic symbols. For example, numerals, electronic schematics, and traffic signs, as well as such common symbols as $, @, +, and &, are logographs commonly found in English.

The phonetic orthographies used in all modern Indo-European languages (e.g., English, French, German, Russian) are alphabetic, and they represent spoken language at the level of phonemes. Al-
though the English alphabetic orthography is based upon the relationship between symbols and sound, it is well known that this relationship is not exact. Symbol-to-sound anomalies such as homophones (hear vs. here) and heteronyms (read pronounced as "reed" or "red") exemplify the irregular nature of the English orthography. Chomsky (1970) suggests that these so-called irregularities provide information concerning the morphology of words—that is, the combination of letters used to form a word provides clues to its origin and function. As a result of these additional clues to word meaning, the English orthography has been called a "morphophonemic" representation (Chomsky).

There are three predominantly logographic systems in the world today: Chinese, Japanese, and Korean. These logographic orthographies use symbols developed in China over 3,000 years ago. Originally, these characters were rudimentary pictographs, but after hundreds of years of cultural evolution they have changed into stylized abstractions (Wang, 1973). Although rudiments of the original pictograph remain, modern Chinese characters cannot be deciphered purely from visual features without a detailed scholarly knowledge of the evolution of the characters. Actually, for Chinese speakers some of the characters provide phonological cues. This is accomplished by augmenting a logographic character with a phonetic component (see Wang, 1981).

Written Japanese and Korean are unique in that they use two separate types of orthographies concurrently—one logographic and the other phonetic. In each case the logographic script is nearly identical to Chinese, whereas the phonetic script is a symbol-to-sound coding for the appropriate spoken language. Thus, a Chinese and a Japanese individual could partially communicate via their written language, but not via either of their spoken ones. This paper will deal only with Japanese orthography. Japanese learn Kana before learning the logographic (Kanji) symbols. There are two separate Kana syllabaries, Katakana and Hiragana, which function in different ways. Hiragana symbols are written in cursive style and serve as grammatical morphemes (e.g., indicating the subject phrase, augmenting verbs). Katakana are more angular in form and are used for borrowed words and foreign proper names. Kanji are used mainly as lexical morphemes. Kanji, Katakana, and Hiragana are used in combination and are all found in everyday newspaper print. A vocabulary of roughly 3,000 Kanji symbols is needed to read newspapers and magazines (Sasanuma, 1974).

The origin of Japanese spoken language is quite different from Chinese. Japanese spoken language evolved from the Altaic family of languages, which includes Turkish and Mongolian (Miller, 1980).
Chinese language, however, is not part of the Altaic language group, and there are substantial differences in phonology between the languages. As a result of borrowing an orthography from a different spoken language, the Japanese have evolved two pronunciations of the Kanji characters—a Japanese pronunciation and an approximation of the Chinese pronunciation. The pronunciation of a logograph is determined by the way the logograph is used in a sentence. Thus, the phonological cues that are associated with many Chinese logographs do not facilitate sounding by a Japanese reader as much as they would facilitate sounding by a Chinese reader. Japanese Kanji, therefore, has been considered to be more strictly logographic than its Chinese equivalent (Hatano, Kuhara, & Akiyama, 1981).

Just as Japanese Kanji is "more logographic" than written Chinese, Japanese Kana is "more phonetic" than many western languages. Each Kana symbol has a virtually invariant pronunciation regardless of its context. As a result of this purely phonetic representation, heteronyms are nonexistent and homophones are more frequent. If the Kana characters were used without the Kanji characters, anyone who knew the symbol-to-syllable translations could read Japanese. This fact raises an interesting issue concerning the role of logographs in Japan. It is not necessary to write Japanese using Kanji, and practically speaking, the use of such complex visual symbols produces technological problems in typing and printing. For example, a Japanese typewriter must provide 2,000 to 3,000 Kanji and about 200 Kana characters. One may question the practicality of such a writing system, particularly for such a practical society. Indeed, both the Chinese and Japanese governments have considered relying more heavily on phonetic orthographies. Is there any functional advantage for logographic orthographies? Do logographic symbols facilitate word comprehension?

Because logographs represent units of meaning rather than units of sound, it has been suggested that logographic orthographies allow more rapid access of meaning than phonetic orthographies (Biederman & Tsao, 1979; Hatano et al., 1981). Phonetic orthographies rely at least in part on phonological recoding processes; that is, the written symbols arouse names which then access meaning. Based on this view, logographic orthographies may allow more rapid access of meaning, though phonetic orthographies may allow more rapid access of names. Thus, reading Japanese or Chinese may involve different cognitive processes than reading English or French. A skilled reader of Japanese may more often utilize processes associated with direct access, whereas a skilled reader of English may more often utilize processes associated with phonological recoding. Reading seems to involve both direct
access and phonological recoding, but the type of orthography may influence the degree to which each function is used.

In studies of English orthography, there is little doubt that phonological recoding contributes to reading (see Coltheart, 1978; McCusker, Hillinger, & Bias, 1981). There is, however, debate about the nature of the contribution (Humphreys & Evett, 1985). Some studies have demonstrated the importance of phonological recoding processes during lexical access (Meyer, Schvaneveldt, & Ruddy, 1974; H. Rubenstein, Lewis, & Rubenstein, 1971). Other studies have stressed the importance of direct visual-to-semantic processes and have suggested that phonological recoding is related only to postlexical operations such as sentence comprehension (Baron, 1973; Kleinman, 1975). The confusion lies in the fact that it is not necessary to associate symbols to sounds in order to comprehend words, as it is possible to treat any written word (logographic or phonetic) as an abstract symbol that allows access to meaning directly. Nevertheless, phonological recoding may contribute to lexical access, and phonetic symbols may have an advantage in associating sounds to symbols.

Many models of word comprehension favor a dual-access conceptualization in which lexical access can occur by way of direct orthographic processes or through phonological recording (Coltheart, 1978; Meyer et al., 1974; Morton, 1969; but see McClelland & Rumelhart, 1981 for an alternative conceptualization). A consistent finding is that the phonology of words and nonwords is accessed in reading tasks and in cognitive tasks, even when it is not necessary, and sometimes disadvantageous, to name the word or nonword (Andrews, 1982; Meyer et al., 1974; Parkin, 1982; Tanelhaus, Flanigan, & Seidenberg, 1980). Thus, it is thought that accessing the name of a symbol is independent of accessing its meaning. These two processes are thought to facilitate reading, but they operate in parallel and independently of each other.

A dissociation between these two processing routes to lexical access—via direct symbol-to-semantic processes and via phonological recoding—can be demonstrated in neuropsychological studies of patients with left cortical brain damage. Some patients appear to have a selective deficit in phonological recoding because they can comprehend the meaning of some concrete words, but they cannot pronounce nonsense syllables or determine if two orthographically dissimilar words (e.g., hope vs. soap) rhyme (Marshall & Newcombe, 1966; Patterson & Marcel, 1977; Saffran & Marin, 1977; Shallice & Warrington, 1975). Conversely, other patients appear to have a selective deficit in direct access; these patients can comprehend words only by rigorously pronouncing each word (Marshall & Newcombe, 1973).
Further evidence for a neuropsychological dissociation between direct access and phonological recoding processes can be found in studies of Japanese aphasics. Sasanuma (1974, 1975) identified a group of aphasics who could not read Kana but could read Kanji. These aphasics were of the anterior type (i.e., Broca’s aphasia) and constituted about a quarter of the sample of 400 aphasics. Sasanuma (1974) also located an aphasic patient with a selective impairment of Kanji. The brain lesion associated with this disorder, called Gogi aphasia, involved temporal-parietal areas but excluded the Wernicke-Broca complex. This patient could write Kana symbols through dictation but was unable to take dictation using Kanji. Comprehension for either script was impaired.

These neuropsychological findings provide tantalizing evidence for a dissociation between lexical access and phonological recoding. It is necessary, however, to view these findings with some caution. Only one case study of a selective impairment of Kanji was found, and this case appeared to show a selective impairment only when translating spoken words to written characters. Thus, the deficit may be related to impaired cross-modal responding rather than impaired reading comprehension (Coltheart, 1982). The selective impairment of Kana appears more frequently and has been replicated (Yamadori, 1975), but there appears to be an impairment of both phonology and syntax. This latter dysfunction is important, because the Hiragana script is used mainly for grammatical morphemes (e.g., indicating the subject; verb endings). Another important finding is that the comprehension of numerals can be preserved in aphasics with severe Kanji impairment (Sasanuma, 1975). Likewise, deficits in understanding numerals can occur without deficits in understanding Kanji (Yamadori, 1975). Thus, impairment of one logographic system does not lead to impairment of all logographic systems.

Studies of the cognitive processes involved in reading have provided further evidence that logographic and phonetic orthographies are not processed in exactly the same manner (for reviews, see Hung & Tzeng, 1981; Kavaunagh & Venezky, 1980; Tzeng & Singer, 1981). Park and Arbuckle (1977) compared long-term memory performance when words were presented using either Chinese logographs or Korean alphabetic script. Free recall and recognition were better when words were written with the logographs. Hatano et al. (1981) tested the degree to which Japanese readers could infer the meaning of unfamiliar words. The ability to do this was better for words written in Kanji than Kana, and the authors concluded that logographs produce efficient access to meaning because they are interpreted at the level of morphemes.
Despite the bias toward direct visual-to-semantic processing, logographs also activate phonological recoding processes. Erickson, Mattingly, and Turvey (1972) found increased errors in an immediate memory task when Kanji characters were phonetically related. Tzeng, Hung, and Wang (1977) found similar effects in Chinese readers when phonetically similar logographs were used in an immediate memory task and in a sentence judgment task in which subjects decided whether sentences were meaningful and grammatically correct. Phonetically similar words produced longer response latencies. These results parallel those found using English orthography in immediate memory tasks (Baddeley, 1966; Conrad, 1964) and in sentence comprehension tasks (Kleiman, 1975). They point to phonological recoding of logographs at relatively later stages of reading.

The Stroop task (Stroop, 1935) is another useful method with which to study the effects of varying orthography (see Dyer, 1973; Jensen & Rohwer, 1966; Preston & Lambert, 1969, for reviews). In this task, the time to name the ink color of stimuli is slowed when stimuli are color names different from the ink color in which the word is written (e.g., the word red written in green ink). This slowing of naming in the presence of conflicting words has been termed the "Stroop interference effect." One use of the Stroop task is to determine the impact of words even when it is disadvantageous to read them. Stroop interference has been attributed to competition at the level of both semantic analysis (Klein, 1964; Warren, 1974) and verbal responding (Posner & Snyder, 1975; Pritchatt, 1968).

Will varying the type of orthography produce different amounts of Stroop interference? If the Stroop test is particularly sensitive to interference at the semantic level, and if logographic symbols access meaning more directly than phonetic symbols, greater Stroop interference should be produced by words written with logographic symbols than words written with phonetic symbols. Biederman and Tsao (1979) tested this hypothesis by comparing Chinese- and English-speaking individuals in the Stroop task for their respective orthographies. They found a greater Stroop interference for Chinese readers and suggested that the direct associations between symbol and meaning produced greater interference in the Chinese version of the Stroop task. Chinese subjects were also slower at word naming and in color naming in the control condition, but these effects appeared to be independent of Stroop interference. Related findings were obtained by Fang, Tzeng, and Alva (1981).

In another study, Smith and Kirsner (1982) compared French-English and Chinese-English bilinguals in a Stroop-like task in which the subjects named objects represented by line drawings in the pres-
ence of conflicting words. Based on previous findings, Chinese-English bilinguals should show greater interference in the presence of conflicting Chinese logographs than in the presence of conflicting English words. Also, the difference in interference between Chinese and English should be greater than the difference in interference between French and English. Neither of these predictions was confirmed.

A general problem with the study of bilinguals is that they are unlikely to have equal proficiency in both spoken languages. Moreover, second-language ability may vary greatly across individuals. In the Smith and Kirsner (1982) study, the Chinese-English bilinguals were from Hong Kong. Biederman and Tsao (1979) used subjects from Taiwan. Another difference between the two studies was that Smith and Kirsner used Chinese words that contained two logographs, whereas Biederman and Tsao used words that could be represented by single logographs. These differences can be avoided by studying the use of first-language logographic and phonetic systems mapping onto the same spoken language. This is possible only by studying Japanese or Korean readers.

The following experiments explored comprehension and naming of logographic and phonetic symbols in both Japanese and English readers. In the first experiment, a Japanese version of the Stroop task was used to clarify the conflicting results of Biederman and Tsao (1979) and Smith and Kirsner (1982). In Experiment 2, English readers were tested on tasks that involved logographic symbols (arrows) and phonetic symbols (words). In Experiment 3, Japanese readers were tested on the same tasks used in Experiment 2, only these tasks involved two types of logographic symbols (Kanji and arrows) and one type of phonetic symbol (Kana). In Experiments 2 and 3, response modality (voice vs. keypress) was also varied to determine if type of stimulus interacts with response modality.

**EXPERIMENT 1**

If words written in Kanji are comprehended better than words written in Kana, a native Japanese reader should display more Stroop interference for words written in Kanji than in Kana. This result is trivial, however, if words written in Kanji are simply more familiar. The qualification is important, because in modern Japanese, color names are usually printed in Kanji. Thus, it is important to show that words written in Kana are at least as closely associated with color names (but not necessarily concepts) as are words written in Kanji. The assumption can be tested by measuring the time required to
name color words printed in a neutral color (e.g., red printed in black ink), using either Kana or Kanji. Actually, if phonetic symbols allow rapid access to phonology, then words written in Kana should be named faster than words written in Kanji.

This hypothesis can be contrasted with a response competition hypothesis described by Morton (1969a) and Posner and Snyder (1975). This hypothesis states that Stroop interference arises from competition between the processing of a verbal name for a word and a verbal name for the ink color. The response competition hypothesis predicts that the faster a word can be named, the greater the interference found in the Stroop task. If words written in Kana are named faster than words written in Kanji, as Feldman and Turvey (1980) have found, then the response competition hypothesis predicts that Kana should produce more Stroop interference relative to Kanji. A differential access hypothesis predicts the opposite—Kanji should produce more Stroop interference despite the propensity for Kana to be named faster.

METHOD

Subjects

Subjects were 16 native Japanese readers (15 males, 1 female), 20 to 35 years of age (median age = 22 years). All subjects received their primary and secondary education in Japan. They had spent from 6 months to 8 years in the United States (median time = 2 years), and all were able to communicate in English. All claimed to have normal color vision and could produce the appropriate names for the colors used in this experiment.

Design

The three Stroop conditions were (a) black print: color names written in black ink, (b) control: colored patches consisting of three colored Xs that conveyed no verbal meaning, and (c) Stroop conflict: color names printed in an incongruous color ink. The black print and the Stroop conflict conditions were presented using both Kanji (logographs) and Katakana (phonetics). This produced five conditions: black print with Kana, black print with Kanji, control, Stroop conflict with Kana, and Stroop conflict with Kanji. Each subject participated in all five conditions.

Stimulus and materials

A separate chart (50.8 x 76.2 cm) was made for each of the five conditions. Stimuli were drawn with Sanford's Sharpie felt-tip pens, using red (aka), yellow (ki), green (midori), blue (ao), and purple (murasaki) ink. Symbols drawn were either colored Xs, single Kanji characters, or Katakana characters (which varied in length from one to four characters depending on the color name). Each chart contained 45 stimuli (three columns of fifteen stimuli), with each color being represented nine times. The colored Xs subtended a
lateral visual angle of 3.2°, and the logographic and phonetic characters subtended an average visual angle of 1.9° and 3.0°, respectively. The ordering of the colors was randomly permuted.

**Procedure**

In the black print conditions, subjects were instructed to read each word aloud starting from the top left corner of the chart. In the other conditions, subjects were instructed to name the ink color of each stimulus. The two black print conditions were always presented first. Next, the control condition and then two Stroop conflict conditions were presented. In the black print and Stroop conditions, the order of the presentation for the two script types was counterbalanced. Subjects were instructed to respond as quickly as possible without making any errors. All responses were made in Japanese; the instructions were given in English. Subjects were tested individually.

**RESULTS AND DISCUSSION**

In the word-naming condition (black print condition), the mean response time was 396 ms for words written in Kana (0 errors) and 521 ms for words written in Kanji (3% errors). The difference in naming latencies was significant, \( t(15) = 6.3, p < .01 \). In fact, all 16 subjects read words written in Kana faster than words written in Kanji.

Table 1 displays the mean response times (RTs) for identifying ink color. Error rates were low and did not indicate speed/accuracy trade-offs. The time required to identify ink color in the Stroop test was longest for words written in Kanji, intermediate for words written in Kana, and fastest for the nondescript colored Xs, \( F(2, 30) = 45.5, p < .01 \).

In summary, words written in Kanji produced more Stroop interference (i.e., longer response times) than words written in Kana, despite the fact that words written in Kana were named faster. The results confirm the findings of Biederman and Tsao (1979) and are consistent with the hypothesis that the logographs used here allowed better or more rapid access to meaning. There is no support for the

<table>
<thead>
<tr>
<th>Condition</th>
<th>Latency</th>
<th>Errors</th>
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<tbody>
<tr>
<td>Conflict</td>
<td></td>
<td></td>
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<tr>
<td>Kana</td>
<td>986</td>
<td>1.1%</td>
</tr>
<tr>
<td>Kanji</td>
<td>1158</td>
<td>3.1%</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patch</td>
<td>743</td>
<td>0.3%</td>
</tr>
</tbody>
</table>
response competition hypothesis. Even though verbal names were elicited faster for words written in Kana relative to words written in Kanji, they did not produce greater Stroop interference. In addition, this finding argues against the possibility that the difference found in the Stroop conflict condition was a result of words written in Kanji being more familiar than the same words written in Kana. Color names are typically written in Kanji, yet these words were named slower when they were written in Kanji than in Kana.

There is, however, another possible explanation for these findings. The mean difference between the two symbol types in the black print condition (396 ms vs. 591 ms) was about equal to the difference found in the Stroop conflict condition (986 ms vs. 1,158 ms). It may be that interference in the Stroop conflict condition occurred because subjects read the words first and then responded to ink color. Thus, the difference between the Kana and Kanji scripts in the Stroop conflict conditions might be explained solely by the difference in the time required to read or identify the symbols. The difference in the Stroop conflict conditions between the symbols, according to this explanation, is due not to more interference or competition in the Kanji condition, but rather to the fact that words written in Kanji are identified more slowly. Therefore, for a given individual, if one verbal stimulus takes longer to name than another, then that stimulus should produce longer response latencies in the Stroop conflict condition.

This interpretation of the Stroop effect is questionable on several grounds. First, subjects were told to respond to ink color and to ignore the words. It was disadvantageous to read the words because they always conflicted with ink color. Second, any manipulation that slows word naming will not slow color naming in the Stroop conflict condition. In fact just the reverse is often true. Gumenik and Glass (1972) reduced the perceptibility of words and found that this manipulation led to an increase in the latency to read words but a decrease in the amount of Stroop interference. This finding concurs with an unpublished study (Shimamura & Hunt, 1981) in which naming latencies in a standard Stroop task for English-speaking individuals were slowed by presenting words upside-down. This manipulation slowed word naming, but produced less Stroop interference as compared with presenting the stimuli right-side-up. Thus any manipulation that increases word-naming latencies will not increase the amount of Stroop interference (dramatic effects of this phenomenon can be found in Dunbar & MacLeod, 1984).

There is a third inconsistency with the suggestion that Stroop interference in this experiment was the result of the time to identify words. If this were true, then word naming and the magnitude of
Stroop interference should correlate with one another. A post hoc analysis was conducted to determine whether the difference in latency between Kana and Kanji conditions in word naming across individuals correlated with the difference in latency between the two conditions in the Stroop test. This correlation was not significant ($r = .168, p > .05$). Thus, it was unlikely that the longer latencies in the Stroop test for Kanji words occurred because Kanji words were more difficult to identify. Instead, the results suggest a dissociation between the access of name codes, which was faster for Kana characters, and the access of meaning, which was faster for Kanji characters. In the following experiments, the time to identify symbols was measured directly in order to reject this alternative hypothesis. In addition, further tests were conducted to establish a dissociation between word naming and lexical access in both Japanese- and English-speaking individuals.

**EXPERIMENT 2**

Experiment 2 investigated the possibility of ‘logographic’ processing by English readers. Visual representations, such as numerals, symbols used in electronic schematics, musical notation, and various common abbreviations (&, $, \%, \text{and} \#) are logographs. Do they behave as do Kanji characters?

Besner and Coltheart (1979) found that numbers represented as digits (e.g., 1, 2) produced more interference in a Stroop-like task than numbers represented as words (e.g., one, two). Subjects were instructed to identify the larger number in a pair of digits. Conflicting information was introduced by varying the physical size of the numbers, so that sometimes the numerically larger number was physically larger (compatible condition), and sometimes the numerically larger number was physically smaller (incompatible condition). The physical size of the numbers influenced response latencies when the numbers were written as digits, but not when they were written as words. Thus, an irrelevant stimulus cue (physical size) interfered more with the comprehension of a logograph than with the comprehension of a word written in a phonetic orthography.¹

Another type of logographic processing occurs when arrows are used to represent direction. Clark and Brownell (1975) conducted a series of experiments in which the compatibility between the direction of an arrow and its position in the visual field was varied. The higher the arrow was in the visual field, the faster the response to an upward-pointing arrow. Likewise, the lower the arrow, the faster the response to a downward-pointing arrow. These findings suggest that pictorial
or logographic information can access semantic processes in a different way than verbal or linguistic information.

In the present study, English readers were asked to indicate the spatial location of stimuli placed either above, below, to the left, or to the right of center. A Stroop-like interference was produced by having the stimuli indicate directions that were incompatible with its position (e.g., the word right located at a position left of center). The incompatible stimuli could be represented by words or by arrows (see Figure 1 for examples). In addition, the latency to identify directions represented by words and arrows was measured to determine the speed with which the stimuli themselves could be identified. Response modality was also varied—subjects made either manual or voice responses.

If arrow stimuli allow better or more direct access to meaning, then they should produce more interference than English words, just as words written in Kanji produce more interference than words written in Kana. Also, English words should be named faster than the direction indicated by an arrow—at least in the voice response mode—because words would allow more direct access to phonology than arrows. By

![Figure 1. Some examples of stimuli used in the spatial location task. (Subjects indicated the spatial location of stimuli [up, down, left, or right] in the presence of compatible [COM] words or arrows, or in the presence of incompatible [INC] words or arrows.)](image)

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using manual and keypress response modes, it was possible to determine whether the manipulation of symbol type (words vs. arrows) interacts with response modality. One possibility is that even though keypress responses do not require overt naming, phonological recoding is still necessary to identify the stimulus. Based on this interpretation, latencies to identify the stimuli in the keypress mode should produce the same general effects as in the voice mode. It may be, however, that arrows are identified faster when making keypress responses, but words are named faster when making verbal responses.

METHOD

Subjects

Twenty-four students from the University of Washington participated in the one-hour experimental session for credit in introductory psychology courses.

Apparatus and stimuli

A computer system, including an Apple II microcomputer, a Panasonic color monitor, and a Mountain Hardware clock, was used to present the stimuli and record RTs. Responses were made using a voice key or a keypad connected to the computer. The keypad consisted of four keys, one situated above, below, to the left, or to the right of a center key. Subjects used the index finger of their dominant hand to make keypress responses. Between trials, subjects placed their index finger on the center key. The voice key was activated at the onset of a verbal response.

The subject was seated about 60 cm from the monitor. A 12 × 12-cm square was displayed on the screen to provide a frame of reference. The stimuli consisted of a 5 × 2.5-cm rectangle. The rectangle either contained a word (up, down, left, or right), contained an arrow pointing in one of the four directions, or was blank. The major axis of the rectangle was aligned vertically for stimuli representing up or down and horizontally for stimuli representing left or right. With this configuration, the words up and down were written vertically and the words right and left were written horizontally. This was done to make the perceptual display of the words similar to that of the arrows.

Procedure

Symbol identification task. Subjects saw a word (up, down, left, or right) or an arrow pointing up, down, left, or right and were asked to identify the direction indicated by the stimulus. The stimuli were presented in the center of the screen, and RT to identify the stimulus was recorded once using voice responses and again using keypress responses. Four blocks of 24 trials were administered to each subject, with each block containing six repetitions of each of the four directions. A block of trials contained only one of the two
stimulus types (words or arrows) and one of the two response modes (voice or keypress). All combinations of stimulus type and response mode were used, thus making four blocks (words-voice, arrows-voice, words-keypress, arrows-keypress). The order in which the blocks were presented was counterbalanced. Four practice trials preceded each block of trials.

**Spatial location task.** Subjects were shown stimuli situated above, below, to the left, or right of center. They indicated the position of each stimulus relative to the center. In the control condition the stimuli consisted of a blank rectangle. Each of the four positions was repeated eight times for 32 trials. In two experimental conditions the stimuli consisted of either words or arrows that were placed within the rectangle. On half the trials the word or arrow was compatible with its location, and on the other trials the word or arrow was incompatible and indicated the direction diametrically opposed to its position (see Figure 1). This design produced eight different stimuli presentations (4 Directions × 2 Compatibility conditions) which were repeated four times for 32 trials. Only one stimulus type and one response mode was used for each block of 32 trials. Four blocks were administered such that all four combinations of stimulus type and response mode were presented to each subject. Prior to each block, four additional practice trials were presented. The presentations of the control and experimental conditions were blocked and their order counterbalanced.

**Response modes.** Each subject participated in the symbol identification and spatial location tasks twice, once using keypress responses and once using voice responses. In the keypress response mode, subjects used the index finger of their dominant hand to make responses. Subjects initiated trials by pressing the center key. In the voice response mode, a voice key timed the latency between the onset of the stimuli and the onset of a verbal response. Trials in the voice mode were initiated by the experimenter, who also recorded errors. Half of the subjects were tested using voice responses first; the other half were tested using keypress responses first. Within each response mode, the symbol identification task always preceded the spatial location task. Each trial consisted of a warning tone, a 1.5-s pause, the stimulus presentation, and a response. The stimulus was turned off immediately after a response was made.

**RESULTS AND DISCUSSION**

Results were based on 23 subjects. The data from one subject was deleted because he made over 15% errors in two of the conditions. Other than for this one subject, errors across all conditions were low and did not exhibit speed/accuracy tradeoffs. Table 2 displays the data from the symbol identification task in which the latency to identify directions represented by arrows and words was measured for both keypress and voice responses. There was no main effect for stimulus type (arrow vs. words) nor was there a main effect of response modality (voice vs. keypress), $F(1, 2) = 1.5$, $p > .2$. These nonsignificant main
Table 2. Mean response times (ms) in the symbol identification task for English readers

<table>
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<tr>
<th>Condition</th>
<th>Mean RT</th>
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<td>Keypress</td>
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<td>641</td>
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<tr>
<td>Arrows</td>
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<tr>
<td>Voice</td>
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<tr>
<td>Words</td>
<td>567</td>
</tr>
<tr>
<td>Arrows</td>
<td>664</td>
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</table>

![Spatial Location Task](image)

Figure 2. Mean response time in the spatial location task. (English-speaking subjects indicated the spatial location of stimuli when the stimuli were blank squares [BLK], arrows, or words. The arrows or words were either compatible with its spatial location [COM] or incompatible with its spatial location [INC].)

...effects were due to a large crossover interaction between stimulus type and response modality, $F(1, 22) = 29.8, p < .001$. Arrow stimuli were identified faster in the keypress condition, $t(22) = 3.6, p < .01$, but words were identified faster in the voice condition, $t(22) = 3.4, p < .01$. Thus, it was faster to point to the direction indicated by arrows, but it was faster to name the direction indicated by words.

Figure 2 displays the data from the spatial location task. An analysis of variance was performed for this task in which the independent variables were stimulus type (arrows vs. words), compatibility (compatible vs. incompatible stimuli), and response modality (voice vs.
keypress). There was a main effect of compatibility, $F(1, 22) = 43.2$, $MS_e = .002$, showing that the irrelevant stimuli affected responses in the spatial location task. There was also a main effect of response modality, $F(1, 22) = 40.6$, $MS_e = .012$, $p < .001$; responses in the keypress mode were generally faster than those in the voice mode. More important, the Stimulus Type $\times$ Compatibility interaction was significant, $F(1, 22) = 16.4$, $p < .001$. That is, the compatibility effect was greater for arrows than for words. Also, the Response Modality $\times$ Compatibility interaction was significant, $F(1, 22) = 18.5$, $p < .001$, indicating a greater compatibility effect under voice responses than keypress responses. Other interactions did not approach statistical significance.

This design included two control conditions. The control condition assessed the ability to respond to spatial location when no irrelevant symbol was present (blank control condition). A separate Dunnett's test of significance between control and experimental conditions was conducted for each response modality. In the keypress condition, the control condition was not significantly different from the two compatible conditions, but produced faster latencies than the two incompatible conditions ($p < .05$). In the voice response conditions, the control condition was significantly faster than all experimental conditions ($p < .05$) except the compatible arrow condition.

These findings paralleled the findings obtained in the Japanese version of the Stroop task (Experiment 1). Logographic symbols (arrows and Kanji words) produced more interference than phonetic symbols (English words or Kana). Moreover, when keypress responses were required, arrows were identified faster than English words. Nevertheless, English words and Kana words were named faster than arrows and Kanji words.

**EXPERIMENT 3**

In the previous experiment, English readers were influenced by arrow stimuli in much the same way that Japanese readers were influenced by Kanji logographs in the Stroop test. In Experiment 3, this relationship was assessed directly in a Japanese version of the spatial location task in which conflicting information was introduced by presenting arrows, words written in Kanji, or words written in Kana. Based on the findings of the previous experiments, Kanji and arrows should produce greater Stroop-like interference in the spatial location task than Kana. Moreover, arrows and Kanji should be identified faster than Kana using manual responses, but Kana should be identified faster than arrows or Kanji using voice responses.
METHOD

Subjects

Twelve native Japanese subjects were paid $5.00 for their participation in a one-hour experimental session. All had received their primary and secondary schooling in Japan and could recognize the Kana and Kanji characters used in the experiment. All subjects had Japanese as a first language. They had spent from 4 months to 3 years in the United States (median time = 1.5 years), and all were capable of understanding English. Instructions were given in English.

Apparatus and stimuli

The same apparatus used in Experiment 2 was used, except that the stimuli were presented using a Kodak slide projector with a tachistoscopic shutter. The projector and shutter were controlled by an Apple II computer. Stimuli were hand-drawn, photographed, and presented as slides. Responses were made using the same keypad and voice key used in Experiment 2.

The display consisted of a 10 × 10-cm square outline that provided a frame of reference for the subject. The display was similar to the computer-generated display used in Experiment 2. In the symbol identification task, an arrow, or a word written in Kanji or Kana was presented at the center of the screen. In the spatial location task, a blank square, an arrow, or a word written in Kanji or Kana was presented above, below, to the left, or right of a center fixation point. All of the words written in Kanji could be represented by a single Kanji logograph. Words written in Katakana had two to three characters and were always presented vertically, as they are usually written in Japanese. Spatial directions represented by Katakana, Kanji, and arrows indicated up (ue), down (shita), left (hidari), or right (migi).

Procedure

Symbol identification task. Subjects identified the spatial direction represented by Katakana, Kanji, or arrows. Stimulus type was blocked, with each block consisting of 16 trials—four spatial directions with each direction repeated four times. Trials within a block were presented in a mixed order. Four practice trials preceded each block.

Spatial location task. Subjects indicated the position of a stimulus relative to the center. In the control condition the stimulus was a blank square situated in one of the four positions with each position repeated six times for 24 trials. In the three experimental conditions the stimuli consisted of either Kana, Kanji, or arrow symbols indicating directions, as described above. On half the trials the symbols were compatible with the spatial location. On the other half the symbol indicated a direction 180° away from the spatial location. For each symbol type, eight different stimulus presentations (4 Directions × 2 Compatibility conditions) were repeated three times for 24 trials. The control and three symbol conditions were blocked and their order counterbalanced. The order of the trials in each block was randomly permuted. Prior to each block, four practice trials were given.
Response modes. The tasks were given once using a voice response and once using a keypress response. Subjects made all voice responses in Japanese. The procedure was the same as in Experiment 2, except that all trials were initiated by the experimenter. Half of the subjects received the voice response first, the other half received the keypress response first. Within each response mode, the symbol identification task always preceded the spatial location task. Each trial consisted of a warning tone, a 1.5-s pause, the stimulus presentation, and a response. Subjects were instructed to respond as fast as possible, but not to make any errors.

RESULTS AND DISCUSSION

In the symbol identification task (see Table 3), a significant Stimulus Type × Response Mode interaction was found, $F(2, 22) = 10.2, p < .01$. Specifically, identification latencies in the keypress modes were fastest for arrows, intermediate for words written in Kanji, and slowest for words written in Kana. Planned comparisons showed that keypress responses to arrows were significantly faster than responses to Kanji or Kana words, $t(11) > 2.4$. The difference between Kanji and Kana words approached statistical significance, $t(11) = 1.85, p = .09$. In the voice response mode, this order was reversed; Kana words were named faster than Kanji words, and Kanji words were named faster than arrows, though these differences only approached statistical significance; Kana words versus arrows, $t(11) = 1.72, p = .1$.

Figure 3 displays the latency data for the spatial location task. There was a main effect of compatibility, $F(1, 11) = 33, MS_e = .002, p < .001$, demonstrating that it was difficult to ignore irrelevant symbols. More important, there was a significant Symbol Type × Compatibility interaction, $F(2, 22) = 4.9, MS_e = .001, p < .02$. That is, averaged over response mode, Kanji produced the largest compatibility effect. Thus, these findings are similar to the findings of Experiment 1 in

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean RT</th>
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</thead>
<tbody>
<tr>
<td><strong>Keypress</strong></td>
<td></td>
</tr>
<tr>
<td>Kana</td>
<td>721</td>
</tr>
<tr>
<td>Kanji</td>
<td>690</td>
</tr>
<tr>
<td>Arrows</td>
<td>607</td>
</tr>
<tr>
<td><strong>Voice</strong></td>
<td></td>
</tr>
<tr>
<td>Kana</td>
<td>636</td>
</tr>
<tr>
<td>Kanji</td>
<td>654</td>
</tr>
<tr>
<td>Arrows</td>
<td>667</td>
</tr>
</tbody>
</table>

Table 3. Mean response times (ms) in the symbol identification task for Japanese readers.
which Kanji words produced more Stroop interference than Kana words.

In addition, the compatibility effect across symbols was not the same for the two response modes, as indicated by the significant three-way interaction, $F(2, 22) = 7.3, MSe = .001, p < .01$. In the keypress mode, planned comparisons showed that the compatibility effect was similar for Kanji and arrows, $t(11) = .569$, but these two effects were reliably greater than the compatibility effect found for Kana $t_s(11) > 2.28$. In the voice response mode, however, the compatibility effects found for Kana and Kanji were not different from each other, $t(11) = .09$, but these two effects were reliably greater than the effect found for arrows, $t_s > 2.31$.

In this experiment, there was also evidence for response competition of verbal names. Voice responses generally took longer than keypress responses, $F(1, 11) = 9.5, MSe = .039, p < .01$, and they also produced larger interference effects, $F(1, 11) = 8.4, MSe = .001, p < .01$.

**GENERAL DISCUSSION**

In the Stroop task (Experiment 1), words written in Kanji produced greater interference than words written in Kana. In the spatial location
tasks of Experiments 2 and 3, arrow stimuli and words written in Kanji produced greater interference than words written in English or Kana. Taken together, the findings demonstrate that the logographic symbols used in these studies (arrows and Kanji words) were more difficult to ignore relative to the phonetic symbols (English and Kana words). Although the logographic symbols produced more interference, they were slower to be named relative to their counterparts written in English or Kana. Thus, the interference effects were not indicative of general familiarity or of the speed with which symbols were named.

The dissociation between naming and comprehension was apparent in the symbol identification tasks used in Experiments 2 and 3 (see Tables 2 and 3). In the voice mode, words written in English or in Kana were named faster than arrows or words written in Kanji. Yet in the keypress mode, arrows and words written in Kanji were identified faster than words written in English or Kana. The reversal of the effect across response modes suggests that identification via verbal responses (i.e., naming) is mediated by a different set of processes than identification via manual responses. The general pattern of these findings is analogous to differential effects found for words and pictures. Words can be named faster, yet drawings of objects can be categorized faster (Potter & Faulconer, 1975; Smith & Magee, 1980; but see Theios & Freedman, 1984).

The findings from the Stroop and spatial location tasks reinforce the distinction between naming and comprehension. The interference effects were not indicative of the speed with which the symbols were named, as would have been predicted by a response competition view (Morton, 1969a; Posner & Snyder, 1975). Particularly compelling evidence for this fact was found by Dunbar and MacLeod (1984), who showed that manipulations that affected naming latency (e.g., using transformed text) did not necessarily affect latencies in the Stroop task. As Dunbar and MacLeod (1984) noted: "Interference is not due to a limited capacity response buffer being filled, but to the amount of priming each potential response receives" (p. 637, italics theirs). Perhaps arrows and words written in Kanji allowed better activation or priming of semantic associates than words written in English or Kana, and this activation affected performance on the Stroop and spatial location tasks. Naming latencies, however, appeared to be related more to the association of symbols with names than to the association of symbols with meaning.

A different explanation for the present findings was proposed earlier as a way to account for differences between orthographies. It was suggested that response latency in Stroop and spatial location tasks
was slowed by the presence of conflicting stimuli, because subjects took time to read and identify the stimuli. By this view, logographic orthographies produced greater Stroop effects simply because they were more difficult to recognize or identify. Although previous findings argue against this interpretation (e.g., Gumenik & Glass, 1972; Shimamura & Hunt, 1981), the strongest evidence against it comes from the results of the symbol identification tasks used here. In these tasks, words written in Kanji and arrows were identified faster than words written in Kana or English when keypress responses were used. Thus, when it was not necessary to name symbols, logographic representations were identified faster than phonetic representations. Stroop effects cannot be explained by arguing that words written in logographic orthographies are more difficult to identify, nor can differences in verbal naming speeds account for differences in Stroop effects.

The findings of the Stroop and spatial location tasks did show some evidence for competition at the level of verbal responding. Interference effects were generally larger in the voice response mode for all stimulus conditions. Other studies of the Stroop task have shown that voice responses produce more Stroop interference than manual responses (Morton, 1969a; Tecce & Happ, 1964). Thus, responses were apparently affected by both competition at the level of verbal responding—just as Morton (1969a) and Posner and Snyder (1975) have suggested—and at the level of semantic analysis. By varying response modality, it was possible to distinguish the interference effects produced at these two levels of analysis.

There were some anomalies in the interference effects produced by the various tasks used here. Arrows produced more interference than English words or Kana words in the keypress mode; but in the voice mode, arrows produced significant interference only for English readers. The Kanji condition for Japanese readers more closely paralleled the arrow condition for English readers. Another anomaly was that in the voice mode there was no difference in the interference effect produced by words written in Kanji versus words written in Kana. Words written in Kanji did produce greater interference in the keypress condition. The finding of greater interference in the keypress mode was critical because in this condition competition at the verbal response level was minimal.

The failure to find a difference in the interference effects between Kanji and Kana words in the verbal response mode is puzzling because greater Stroop interference was found in the verbal mode for words written in Kanji (Experiment 1). There were, however, several differences between the designs used in the Stroop and spatial location
tasks that may account for this discrepancy. First, the Stroop task was presented in its standard form: Subjects viewed a chart of color words written in different colors and the time to respond to all stimuli on the chart was recorded. In the spatial location task, stimuli were presented individually and RT to each stimulus was recorded. Second, in the Stroop color test each conflicting stimulus could take one of four values. In the spatial location task, each conflicting stimulus could take one of two values. Perhaps conflicting stimuli that can take on more values or that are presented in a list rather than presented individually produce greater semantic interference. In the voice mode of the spatial location task, effects of semantic interference may have been overridden by verbal response competition.

The present findings do not necessarily suggest that naming simply reflects on-line phonological recoding (i.e., the application of grapheme-to-phoneme conversion rules). In fact, Besner, Hildebrandt, and McCann (1984) found evidence against this view. They found that real words written in Kana were named faster than pseudowords written in Kana. Thus, Japanese readers do not simply apply grapheme-to-phoneme rules while reading Kana; if they did, then the latency to respond to words and pseudowords would be the same. In another study, Seidenberg (1985) found that Chinese logographs that contained phonetic cues were named faster than nonphonetic logographs, but only if the logographs were low in frequency. Response times to name high-frequency logographs were not influenced by the presence of phonetic cues. These findings more specifically define the effect of phonology on word naming and suggest that phonological codes of whole words may also reside in memory.

In summary, by manipulating orthography it was possible to dissociate the processes underlying word comprehension and naming. The logographic symbols used in these studies (Kanji and arrows) were identified faster than their counterparts written with phonetic symbols (Kana and English words). Yet, the phonetic symbols were named faster than the logographic symbols. Moreover, the logographic symbols produced more Stroop interference than the phonetic symbols. These results were found for both Japanese and English readers, and they suggest differential access to meaning and phonology.

Notes

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1. A study by Foltz, Poltrock, and Potts (1984) suggests that the absence of a size-congruity effect for numbers written as words may be artifactual. Despite this complication, they did find that incongruous size affected the comprehension of numbers written as digits more than the comprehension of numbers written as words.

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