■Special Lecture

Basic Processes of Reading

——Do they Differ in Japanese and English?——

K. E. Patterson*

The basic processes of reading involve two computations based on the orthographic information in the written word : (a) computation of a phonological representation, corresponding to the pronunciation of the written word, and (b) computation of a semantic representation, corresponding to the (or rather a) meaning of the written word. There is substantial variation in the principles by which different orthographies reflect the meanings, and in particular the pronunciation, of the words in their languages. The purpose of this paper is to discuss the implications of these different principles for the basic processes of reading. Does reading in such different orthographies as Japanese kanji, Japanese kana and the English alphabet involve qualitatively different procedures for transcoding from orthography to phonology and from orthography to meaning? This question was first brought to prominence in a series of papers by Sasanuma (1980 ; 1984 ; 1986) based on detailed studies of adult neurological patients with acquired disorders of reading in Japanese. The question will be addressed here with evidence, for each of the three orthographies, from both normal and impaired adult readers.

The hypothesis proposed is that, despite their real and major differences, the three orthographies used in Japanese and English do not give rise to crucially different transcoding procedures. In an extension of the time course model developed by Seidenberg (1985), it is suggested that the transcoding procedures of kanji, kana and alphabetic English differ only in detail, particularly in the time course of processing. (See also Shimamura, 1987, for a related account and discussion). Figure 1 represents a version, at a descriptive level, of a model of basic reading procedures. The part of the model in bold outline has been implemented as a working, computational simulation trained on a vocabulary of about 3000 English words (Seidenberg & MaClelland, 1989 ; see also Patterson, Seidenberg & McClelland, 1989). The model proposes that when a reader encounters a written word, phonology and meaning for that word are both computed automatically and in parallel. The present hypothesis, that the same basic processes are characteristic of all three orthographies, is indicated in the figure by the fact that a word in each orthography (いちご in kana, TABLE in English, 切手 in kanji) causes the corresponding pronunciations("ichigo", "table", "kitte") and meanings (strawberry, table, stamp) to be activated. Note that, since each type of representation is connected

*Medical Research Council Applied Psychology Unit, 15 Chaucer Road, Cambridge CB2 2EF, UK

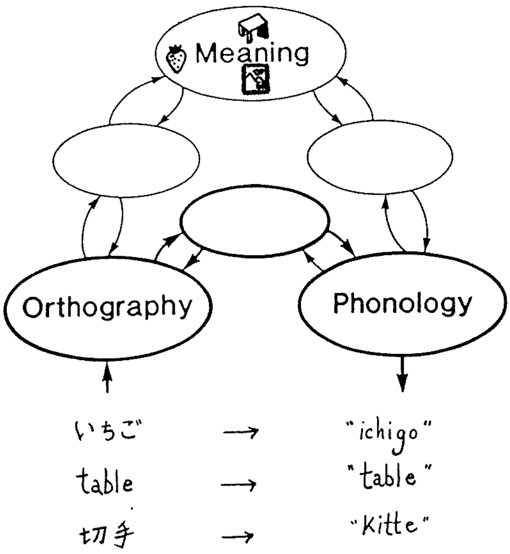

Figure 1

to each of the two others, transcoding from one to another can occur either directly(e. g., orthography straight to meaning) or in directly (e. g., from orthography to meaning via phonology). For simplicity, the two direct transcodings from orthography will be abbreviated as ORTH→PHON and ORTH→MEANING, and the two indirect transcodings as ORTH→(MEANING)→PHON and ORTH→(PHON)→MEANING.

According to Seidenberg(1985), the speed with which a reader can compute ORTH→PHON will depend on a variety of factors, including for example the skill of the reader, the nature of the reading task, and the frequency or familiarity of the words to be processed. The factor of particular importance when considering this proposal across different languages is the nature of the relationship between the language's orthography and its phonology. The basic principle suggested here is that the more generalisable and rule-governed this relationship is, the quicker and more efficient ORTH→PHON will be. How generalisable and rule-governed an orthography is can be roughly equated with the degree to which individual characters of the orthography correspond to single, unambiguous phonological segments, independent of the orthographic context in which they occur. As suggested by Sasanuma (1986), various writing systems form a kind of continuum in this regard, with Japanese kana at or near the rule-governed end, Japanese kanji at or near the opposite end, and the English alphabet somewhere in between. A brief review of some characteristics of these three writing systems will demonstrate why they are placed in these positions on the continuum.

In kana, a given character essentially always translates to the same mora of spoken Japanese. The only "exception words" in kana are a few grammatical particles (e. g., the particle WA is written with the hiragana character for HA) ; otherwise, every word in kana is written exactly as it is pronounced. There is also no context sensitivity : apart from pitch accent, a given kana character such as た in one context (e. g., たまご) has exactly the same pronunciation as that character in another context (e. g., かるた). Thus the relationship between orthography and phonology is highly generalisable and rule-governed, and the ORTH→PHON computation for any given kana letter string will be straightforward, efficient and fast.

In alphabetic English, letters or letter clusters translate to phonemes, but not in a perfectly predictable manner. There is context sensitivity : for example, the letter C is pronounced/k/when followed by A (as in CALL) but/s/when followed by E (as in CELL) ; for another example, the letter combination TH is typically voiced at the beginning of a function word (e. g., THE or THAT) but typically unvoiced at the beginning of a content word (THING or THOUGHT). English also has many "exception words" : for example, 12 of the 13 monosyllabic words ending in _INT (e. g., MINT, HINT, PRINT) follow the rule-governed pronunciation, but one (PINT) disobeys the rule. Thus the relationship between orthography and phonology in English is quasi-regular (Seidenberg, 1989); relative to an orthography like kana which is highly rule-governed, the ORTH→PHON computation in English will be more complicated, therefore less efficient and not as fast.

In Japanese kanji, the same character can have a number of different pronunciations depending on its orthographic context. For example 言 corresponds to "gen" in the word 方言, to "gon" in the word 無言 and to "koto" in the word 言葉. This situation is not only entirely unlike the highly regular relationship between orthography and phonology in kana ; it is also very different from the quasi-regular relationship of the English alphabet. None of the various pronunciations of a kanji could be called "regular" or rule-governed, with other pronunciations deviating from that rule. The correct pronunciation of a character in each context must simply be learned as a specific instance. Therefore, overall, the relationship between orthography and phonology in kanji is not generalisable.

What are the implications of these varying orthography-phonology relationships for the time course of word processing in English, kana and kanji? Although one cannot state categorically that it takes X amount of time for a reader to compute phonology or meaning for a written word, various experiments requiring readers of English to perform these computations suggest two facts about the time course of processing for English alphabetic reading : (1) the two types of transcoding are not dramatically different in speed, but (2) on average, ORTH→PHON is somewhat faster than the parallel and independent computation of ORTH→MEANING. (For relevant data, see Bajo, 1988 ; Potter et al, 1986 ; Smith & Magee, 1980). This means that in English, one will tend to find an influence of a word's pronunciation in computing its meaning (see Van Orden, 1987, for evidence to support this claim). The explanation for this in terms of the model described in Figure 1 is that all transcodings, indirect as well as direct, are computed automatically. Since ORTH→PHON is generally the faster of the two direct computations, sometimes the indirect computation ORTH→(PHON)→MEANING will be swifter than the direct computation ORTH→MEANING.

Because ORTH→PHON is more efficient and therefore faster in kana than in English, the influence of a phonological representation on computation of meaning should be even more pronounced in kana ; and because ORTH→PHON is less efficient and therefore slower in kanji than in English, the influence of phonology in computing meaning should be less pronounced in kanji. None the less, the basic hypothesis with which this discussion began still holds : in all three orthographies, phonology and meaning can be computed independently from orthographic information.

Note that this is by no means a universally agreed principle about reading in orthographies as different as English, kanji and kana. For example, Bridgeman (1987) suggested that for orthographies like kana which transparently represent phonology, readers might never develop any procedures for word processing other than those base d on phonological coding. This idea has al so been explicitly proposed by Turvey, Feldman & Lukatela (1984) for the phonologically transparent alphabetic orthography of Serbo-Croatian. On the opposite side of this coin, it has often been assumed that since kanji represents units of meaning, pronunciations of kanji words might be retrieved exclusively by ORTH→(MEANING)→PHON (see Morton & Sasanuma, 1984, for discussion). The present proposal is that the same parallel and independent transcoding procedures exist for these three (indeed, probably for all) orthographies, and that differences in processing are to be found only in the detailed aspects and the relative speed of these basic computations.

Evidence for the independent existence of the two transcoding procedures in the three orthographies will now be reviewed, first from experimental studies of normal adult readers, and then from studies of adult neurological patients with acquired disorders of reading.

Evidence from Normal Reading

English

ORTH→PHON independent of meaning. TRID is not a real word in English ; therefore it has no meaning. But any normal reader of English can pronounce written nonwords like TRID, demonstrating that in the English alphabet, orthography can be converted to phonology completely independent of meaning. Further evidence that direct transcoding of orthography to phonology in English can actually influence the computation of meaning is the fact that normal readers sometimes confuse the meanings of homophonic words like PAIR and PEAR. If reading comprehension were achieved exclusively by ORTH→MEANING, then a word with the right sound but the wrong orthography should not be comfusing.

Evidence of such sound-based errors in English comes from experiments involving comprehension of single words or sentences. Subjects (normal adult English readers) are asked to judge rapidly whether a written sentence (e. g., HE BOUGHT A PEAR OF GLOVES) makes sense, or whether a written word is an instance of a specified category (e. g., Is it a kind of fruit? PAIR). The answer to both of these examples should be "no". Experiments with the sentence paradigm (e. g., Coltheart, Laxon, Rickard & Elton, 1988) and with the single word technique (e. g., Van Orden, 1987) both reveal false positive rates in the range of 10-25% when the incorrect target word is a homophone of the correct item, as compared to a significantly lower error rate (0-5%) with appropriate control words.

ORTH→MEANING independent of phonology. Although it does not constitute conclusive proof that English readers comprehend written words without reference to phonology, the fact that they are much more likely to say "no" than "yes" when asked whether a PAIR is a fruit is at least consistent with the idea of direct computation of meaning from orthography. Furthermore, although correct "no" responses to homophone foils like PAIR have significantly longer mean response times than control items, Van Orden (1987 ; see also Van Orden, Johnston & Hale, 1988) has demonstrated that this significant difference is attributable to a small proportion of responses in the slow tail of the RT distribution. With these few responses eliminated, the distributions of correct "no" RT's to homophone and control items do not differ. On the majority of occasions, then, it appears that a reader of English will not be misled or delayed by phonology in computing meaning from orthography.

Kana

ORTH→PHON independent of meaning. It is clear that kana orthography can be transcoded to phonology independent of meaning : for example, Japanese readers easily name kana nonwords such as けこし ("kekoshi"). It has indeed been a typical assumption (see Morton & Sasanuma, 1984) that words written in kana are always processed and comprehended in terms of their phonology. One demonstration of the speed and efficiency of phonological processing in kana is the fact that naming of words normally written in kanji (words which are therefore familiar as whole orthographic strings only in kanji) is nonetheless significantly faster, by an average of about 100 msec, when the words are transcribed into kana (Goryo, 1987 ; see also Feldman & Turvey, 1980 ; Shimamura, 1987). For kana, then, it is non-phonological processing that is controversial and in need of evidence.

ORTH→MEANING independent of phonology. The two forms of kana, hiragana and katakana, are exact phonological equivalents of one another, and are equally easy for any current-day literate Japanese person to read. Therefore, if orthographic processing in kana were merely a matter of transcoding to phonology, it should not matter whether a particular word is written in hiragana or katakana. There are now, however, several studies demonstrating the importance of orthographic familiarity for kana word forms. Japanese readers give significantly faster responses, both in word naming and lexical decision experiments, when a word is presented in its visually familiar kana form (e. g., UCHIWA in hiragana, KAMERA in katakana) than in the alternate kana orthography (UCHIWA in katakana, KAMERA in hiragana) (Besner & Hildebrandt, 1987 ; Besner, Patterson, Hildebrandt & Lee, 1990 ; Sasanuma, Sakuma & Tatsumi, 1988).

Kanji

ORTH→MEANING independent of phonology. Just as a typical assumption for kana has been that its processing is dominated by phonology, a typical view of kanji reading is that its processing is dominated by direct transcoding to meaning. Although 橋 and 端 have identical pronunciations, Japanese readers easily understand the former word as meaning "bridge" and the latter as meaning "corner" or "angle", suggesting that kanji comprehension normally proceeds without influence from phonology. Experimental evidence consistent with this idea is that, although response times in word naming are faster for kana than kanji, processing in word comprehension tasks is often faster for kanji than kana (Goryo, 1987 ; Shimamura, 1987).

ORTH→PHON independent of meaning. Wydell (1989) has applied the Van Orden (1987) paradigm described above to kanji, and obtained similar results. On most trials, Japanese adult readers correctly reject a word like 推薦 as a member of the category 花 (of which 水仙, homophonic with 推薦, is an instance) ; nonetheless, subjects are more error-prone on homophonic foils than on appropriate control words, especially when the homophonic foil is also visually similar to the real category instance.

Needless to say, much remains to be learned about basic reading processes in all of the three orthographies considered here ; but existing evidence from normal adult readers, only briefly and selectively reviewed above, is at least consistent with the idea of independent transcoding from ORTH →PHON and from ORTH→MEANING in all three writing systems.

Evidence from Acquired Disorders of Reading

The claim of this paper is that the two transcoding procedures, ORTH→PHON and ORTH→MEANING, are relatively independent cognitive modules. It is generally accepted (see for example Fodor, 1983 ; Marr, 1982 ; Shallice, 1988) that such independent modules should be differentiated not only by their cognitive representations and procedures but also by their neurological bases. Brain lesions should therefore yield behavioural evidence of double dissociation between independent modules. This section reviews such evidence for each of the three orthographies, organised in the same fashion as the preceding section on evidence from normal reading. The neuropsychological evidence included here is restricted in two respects.

First of all, evidence will be drawn exclusively from single-case studies, not from groups of patients. Even in the unlikely event that one could find a group of patients with the same lesion site/size and the same general symptom complex, variability in performance amongst such a group of patients makes it hard to draw clear theoretical inferences. As argued persuasively by Caramazza (1986), such inferences are based more appropriately on data from single patients than on average performance of groups. Although in some instances a number of relevant case studies are available in the literature, for the sake of brevity only one case will be presented for each combination of orthography and transcoding procedure.

Secondly, the goal here is to assess neuropsychological evidence regarding cognitive processes and psychological models of these processes. Although it is important to establish any available information about aetiology and locus of lesion, it is the relationship of the patient's behaviour to the processing model, not to the lesion site, that will be emphasised.

English

ORTH→PHON independent of meaning.

Patient WLP (Schwartz, Marin & Saffran, 1979 ; Schwartz, Saffran & Marin, 1980), a case diagnosed as pre-senile dementia, showed excellent word naming combined with poor written word comprehension. On higher frequency words, her performance was above chance(though far from perfect) on a very general semantic judgement such as matching a written word to a category label (e. g., ANIMALS), but at chance for the more specific task of matching these written names to their corresponding pictures. On lower frequency words, her performance did not exceed chance level on either of these semantic tasks. By contrast, her oral reading of both high and low frequency words was 90-100 % correct. At a later stage in her dementing illness, WLP began to make regularisation errors in naming words with an irregular spelling-to-sound correspondence (e. g., pronouncing the irregular word COME as if it were a regular word like HOME) ; but at the stage from which the data above are reported, she correctly named difficult written words like TORTOISE and LEOPARD but was unable to match them to their corresponding pictures or even to judge that they represent animal names.

ORTH→MEANING independent of phonology. Whereas WLP (Schwartz et al, 1980) named 100% of high frequency written animal names but was no better than chance at matching them to pictures, PW (Patterson, 1979) correctly matched 100% of animal words to pictures but succeeded in naming only 63% of the written words. This patient, who had suffered a major CVA in the territory of the left middle cerebral artery, showed a pattern of reading performance known as deep dyslexia (Coltheart, Patterson & Marshall, 1980). Further indications that his oral reading reflects the computation ORTH→(MEANING)→PHON, with essentially no contribution from direct ORTH→PHON, are (1) that he scored zero when asked to name simple written nonwords like TRID or FEP, and (2) that many of his word naming errors showed semantic analysis of the stimulus word (e. g., TURTLE named as "crocodile", SHADOW named as "ghost").

Kana

ORTH→PHON independent of meaning. Patient KK (Sasanuma, 1980 ; 1986), following removal of a left posterior temporal hematoma, showed somewhat impaired comprehension of words written in either kanji or kana. Although his naming of words written in kanji was also poor, he maintained good oral reading ability for kana, scoring from 82-100% on different sets of kana words varying in word class and familiarity. Of the six patterns reviewed here, this case represents the least dramatic dissociation, perhaps for the following reason : for any patient with reasonably good ability to name printed words aloud, tests of written word comprehension will only show poor performance if auditory comprehension is also severely disrupted.

ORTH→MEANING independent of phonology. On a list of concrete nouns written in kana, patient SN (Sasanuma, 1986) achieved a score of 80% (chance=25%) in matching the words to their corresponding pictures. This is precisely the same comprehension score as that of patient KK, described above, on the same kana words. However, whereas KK named 95% of these kana words correctly, SN managed to read aloud only 35% of the words. Since his naming of the same words written in kanji was good, SN's poor ability to translate kana to pronunciation cannot be attributed to difficulties in the production components of oral reading. It seems that SN, who had suffered a left temporo-parietal CVA, constitutes evidence for at least partial preservation of transcoding from ORTH→MEANING for kana without reliance on phonology.

Kanji

ORTH→MEANING independent of phonology. YH (Sasanuma, 1980) was a Broca's aphasic and deep dyslexic patient following a CVA in the territory of the left middle cerebral artery. Her kana word naming was virtually zero, and her kana nonword naming was actually zero. She retained some limited ability to name words written in kanji, but much more substantial performance in comprehending these kanji words, as measured by word-to-picture matching. Like the English deep dyslexic mentioned above, many of YH's errors in oral reading of kanji reflect completely the wrong phonology but at least approximately the right meaning.

ORTH→PHON independent of meaning. The newest and most dramatic evidence to be presented here also addresses one of the most controversial aspects of the hypothesis : the idea of direct transcoding from kanji to pronunciation without semantic mediation. Sasanuma, Sakuma & Kitano (1990) present a longitudinal study of SK, a patient with Alzheimer's Dementia. Over a period of about a year, the patient's ability to match words written in kanji to corresponding pictures dropped from nearly perfect to chance. At the end of this period, the patient could not even exceed chance levels on the simplest yes-no judgement (e. g., "is it an animal?") regarding kanji words. Nonetheless, over this period of time, SK's performance in naming words written in kanji remained virtually flawless.

Table 1 provides a summary of relevant aspects of performance for the six cases briefly reviewed above. The naming score in each case simply represents the percentage of words, written in the orthography of interest, that the patient was able to read aloud correctly. The comprehension score represents the percentage of words, again written in the appropriate orthography, for which the patient chose the correct corresponding picture out of four choices (therefore chance = 25 %). Wherever possible, the matching test used is a written version of the Peabody Picture Vocabulary Test (Dunn, 1965) ; where data from this exact test are not available, the closest equivalent in the patient's published results has been used. Many factors determine a patient's absolute level of performance on a particular test ; furthermore, it is not the case that exactly the same word lists were used with these patients. Therefore it would be inappropriate to concentrate too closely on absolute levels of performance or to compare actual numbers across patients. The point to be made about Table 1 is simply that a double dissociation between naming and comprehending written words can be found in neurologically impaired readers of the English alphabet, Japanese kana, and Japanese kanji.

Table 1

Results for six patients (evidence for ORTH→PHON : English = WLP, Kana = KK, Kanji = SK ; evidence for ORTH→MEANING : English = PW, Kana = SN, Kanji = YH) comparing the patient's performance on written words in two tasks : naming (oral reading) and comprehending (matching to pictures)

	ORTH→PHON			ORTH→MEANING		
	Naming		Comprehending	Naming		Comprehending
English	95%	>	13%	47%	<	89%
Kana	82%	>	66%	8 %	<	52%
Kanji	95%	>	20%	12%	<	72%

Concluding Remarks

To use a statistical metaphor, this paper has a 3 x 2 x 2 design : 3 orthographies (the English alphabet, Japanese kana, Japanese kanji) x 2 basic processes of reading (transcoding ORTH→PHON and ORTH→MEANING) x 2 sources of evidence (normal adult readers, and adult subjects who were normal readers prior to brain injury resulting in some form of acquired reading disorder). The purpose of this design was to assess the hypothesis that in all three orthographies, the skill of reading involves the automatic and parallel operation of both basic transcoding processes. To the extent that ORTH→PHON and ORTH→MEANING are separable cognitive modules, one should be able to observe (a) their (relatively) independent contributions to normal performance in reading tasks, and also (b) their susceptibility to double dissociation as a consequence of brain lesions.

The review presented here is necessarily brief, due to space limitations ; in some regards, it is also necessarily inconclusive, because sophisticated experimental designs and appropriate types of patients are only beginning to be explored. With these caveats in mind, the evidence seems most consistent with the hypothesis that the same two basic processes of reading are characteristic of all three orthographies. The precise details of th ORTH→PHON and ORTH→MEANING computations probably differ from one orthography to another; the time course of these computations clearly differs from one orthography to another. At a more general level, however, the three very different writing systems seem to be processed by their readers in similar ways.

It should be clear that this conclusion is meant to apply to the restricted domain of reading considered here : the basic processes of computing a pronunciation and a representation of meaning for an orthographic stimulus. There are other aspects of reading where genuine qualitative differences in processing may arise from the nature of kanji, kana and the Roman alphabet. For example, these three sets of characters (in fact, four, since kana subsumes hiragana and katakana) are really rather different entities with respect to visual complexity, intra-set similarities, and so on. Early visual processing in reading may therefore be a source of qualitative differences between readers of these various writing systems. Thus Japanese and English patients with impaired discrimination and identification of characters/letters may turn out to have distinctive rather than similar features.

It is also worth noting that differences across orthographies in the detailed nature of the basic computations, and particularly their timing characteristics. may be of considerable importance. This cannot be assessed until researchers develop experimental techniques and computational models to investigate the time course of processes like ORTH→PHON and ORTH→MEANING.

The goals of research in cognitive science and neuroscience can and must be an understanding of basic cognitive processes across, not within, languages and cultures.

Acknowledgements

This paper is based on a lecture, entitled "Patterns of Impairment of Written Language in Japanese and English", presented to the 13th Annual Meeting of the Neuropsychology Association of Japan, Tokyo, September 1989. I am deeply grateful to Dr. Sumiko Sasanuma for inviting me to address this meeting, and for providing me with the opportunity to learn about neuropsychological research in Japan. I also thank Taeko Wydell for patiently and expertly answering my endless queries about Japanese language and orthography.

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