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Cognitive processing of Chinese characters, words, sentences and Japanese kanji and kana: An introduction

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Over the past fifty years or so the process-oriented approach has been used to explore the general properties of language systems within the framework of human cognition (Alegria, Holender, Morais & Radeau 1992). While much of this work in information processing deals with the English language, there is increasing realization that we need to understand better the similarities and differences in processing lexical items in different alphabetic language systems and also non-alphabetic systems such as Chinese and Japanese (Frost & Katz 1992).

Within alphabetic language systems there are fine-grained differences in cognitive structures as the orthographies convey not just phonologic information but also morphologic information. Take as an example the Semitic Hebrew language. The abstract structure of the Hebrew word is formed by the juxtaposition of the root, which consists of consonants, and the phonological pattern, which consists of vowels ('matres lectionis' or 'mothers of reading') or a sequence of vowels and consonants. Naming Hebrew words is achieved by 'addressed' phonology through an interactive process of computing a phonological representation of converting letters or letter clusters into phonemes or syllables (Frost 1995; Shimron 1993). For Romance languages such as Portuguese and Spanish, which are syllable-timed with phonemic constraints operating on syllables, easier access to phonology might suggest slightly different mechanisms in reading as compared with English (Morais 1995). For readers of the highly regular Dutch alphabetic language system, research findings with children indicate that grapheme-phoneme conversion can go on in parallel with the lexical look-up in cascading processes (see Leong & Joshi 1997). The use of different levels of information in visual recognition and naming of Dutch can be explained by an interactive-activation model such as the updated dual-route model of Coltheart, Curtis, Atkins and Haller (1993).

From the summary discussion of fine-grained differences in cognitive processing of different alphabetic written language systems, some interesting

research questions pertain to the application of theories and findings to lexical access of the non-alphabetic Chinese and the Japanese language systems. Chinese is morphosyllabic, which incorporates a phonological basis in analytic word reading as shown in psychological analyses (e.g., Perfetti & Zhang 1995). But the phonological processing may not involve segmental analyses of phonemes and morphophonemes, and is more paradigmatic in nature. To what extent is word recognition and naming in Chinese aided by phonological representation? In the case of the bi-scriptal (kanji and kana), or more correctly the tri-scriptal (kanji, hiragana and katakana) Japanese syllabary, the processing of kanji symbols with their On- and Kun-reading to represent meaning and of kana symbols with their moraic segments to represent subsyllabic and timing units may involve different cognitive structures.

The research papers in this Special Issue are attempts to answer the above questions, and more. These papers are grouped into two sections, one dealing with Chinese and the other dealing with Japanese. As is evident, there are common processing mechanisms cutting across these two written language systems.

Processing Chinese

Over the past twenty years or so there have been major volumes on the processing of Chinese, including those by Kao and Hoosain (1984, 1986), Liu, Chen and Chen (1988), and Chen and Tzeng (1992) in addition to research articles in psychological journals. Some of these and other authors who have been working long and hard in this field are represented in this Special Issue. There have been advances in theoretical models in accessing Chinese buttressed by research findings from more refined experimental techniques.

Tan and Perfetti provide a critical review of current research findings in accessing the morphosyllabic Chinese; and marshall cumulative evidence to argue forcefully for the 'identification-with-phonology' hypothesis. This postulate is articulated and tested empirically by Perfetti and his colleagues in a series of experiments with Chinese single- and double-characters and using converging priming, forward and backward masking experimental techniques. Phonology is shown to be playing a central role in Chinese word recognition and phonological information is activated at the same time as 'complete graphic recognition', which is explained as at the same moment when there is sufficient activation of a character's orthographic representation to differentiate it from other representations.

Phonology is activated earlier than semantics and may influence meaning, though not necessarily mediating it, according to Tan and Perfetti. The time

course in meaning access is a function of, among other things, the word's different layers of meanings. Tan and Perfetti discuss pervasive homophony in Chinese characters and their inherent 'homophony density', or shared pronunciations, in bringing about the concomitant 'phonological diffusion' effect to account for early phonological processing, rather than phonological mediation.

In two priming experiments with varying prime-target exposure duration, *Weekes, Chen and Lin* found that homophone primes facilitated the recognition of 'compound' Chinese characters (those with separate radical constituents) but not 'integrated' characters (those without separate radicals). There was, however, significant semantic priming effects for both compound and integrated characters. Weekes et al. explain the phonological facilitative effects on compound characters as due to increased phonological activations from competition between different phonological forms for the correct pronunciation of a compound character; and the null effect for integrated characters at different priming exposure stimulus-onset-asynchrony (SOA) as resulting from the absence of this competition. The semantic priming effects are seen as the effects of the orthographic and semantic nature of the Chinese orthography. The authors acknowledge their results might be affected by the nature of the recognition task itself. In their experiments, Weekes et al. found partial support for the '"universal" phonological principle' postulated and tested empirically by Perfetti and his Pittsburgh group.

Continuing the theme of phonological processing of Chinese, *Li and Yip* examined in two gating experiments spoken homophones and the role of context in processing them. The gating technique uses successive presentations of incremental temporal durations in presenting target words to assess the timing influence on speech perception and word recognition. The evaluation of context effect is predicated on the assumption of changes across different levels of gating. Experiment 1 studied the contextual effects on native Chinese university students' identification of spoken Chinese homophones with high and low density and varying match with prior sentence contexts. Experiment 2 examined Chinese-English bilinguals' processing of cross-modal homophones in a naming task in which Chinese sentences embedding English test words spoken in Cantonese phonetics were presented auditorially and following by visual probes at a given SOA.

Among other results, Li and Yip's finding of limited Chinese tonal information effect on homophone processing in relation to sentential context is significant in that different levels of Chinese tones may be analogous to the coarticulation effects of phonemes. In English, Mann and Repp (1981) have shown that the recognition of the following segment as /t/ or /k/ is affected by the speech environment of the preceding segment such as /s/. Li and Yip

predicate their work on the TRACE model of speech perception, in which information processing takes place through interactive-activation of different processing units such as phonemes and words and by making sequential, categorical decision about the identity of these units. The TRACE model with its multiple representations of the same lexical candidates for different moments of time allows for segmentation and linearity; and further research should include larger lexical and longer continuous input strings (Altmann 1990).

The extraction of visual information from the printed page of Chinese and the shape and size of the effective visual field in reading Chinese are the main focus of the study by *Chen and Tang*. These researchers used a self-paced moving window technique to study the perceptual span or the area of text around the fixation point that is functionally important to reading. They found from the critical word location (CWL) and mean character viewing time measures that the effective visual field in reading Chinese was asymmetric and skewed in the direction of scanning with a fairly limited size consisting of the fixated character and about two characters to its right. This finding of the asymmetry of the perceptual span suggests the tendency to anticipate the direction for the uptake of new information and extends the earlier work of Chen and his colleagues. Chen and Tang emphasize the importance of reading research across orthographies to examine in greater detail both universal and orthography-specific encoding processes.

On sentence comprehension, the traditional psycholinguistic approach to parsing English sentences relates to hierarchical tree-diagram constructs. There are now more open-ended connectionist sentence processing models to deal with such issues as Subjacency Condition of Chomsky's bounding theory (1986), which allows movement out of one syntactic constituent in a single operation. There are also attempts to explain the parsing of long-distance dependencies when relative clauses can be attached to several potential heads.

Even though much of the work on sentence processing deals with the English language, there are on-line studies of parsing Japanese sentences (e.g., Mazuka 1991) and Chinese sentences (e.g., Liu 1980). Mazuka (1991) provided experimental data to show that the processing of Japanese empty categories (e.g., trace of WH-movement and NP-movement) by native speakers may be delayed until after the on-line processing of the structure of a sentence. These 'preliminary' experimental data suggest possible differences form processing English sentences. In his ongoing work, *Liu* attempts to tease out Chinese sentence comprehension and verification time. In two experiments in the present paper Liu investigated the comprehension of simple subject-verb-object (SVO) Chinese sentences by manipulating experimentally the reference scope (number of pictures verifying the truth valency

of propositions) and the location of superordinate and subordinate concepts in integrating these propositions. Robust effects of both scope in terms of truth valency and location in relation to superordinates and subordinates were found in comprehending Chinese sentences. Liu suggests that a slot-filling model of sentence comprehension explains well the integration of successive constituents of sentences not only for Chinese but also for English.

Moving from Chinese sentence processing, *Law, Ki, Chung, Ko and Lam* report on the writing of Chinese characters by young children. In particular, they studied in some detail the mastery of stroke sequences and common errors made by Chinese children in writing characters. Children's sensitivity to character formation rules, basic stroke forms and sequences in stroke movement is suggested as the cognitive basis for the production of correct written Chinese characters. The analyses by Law et al. provide insight into an integral aspect of learning Chinese.

Processing Japanese

Modern Japanese writing system consists of kanji and kana scripts, or, more correctly, kanji, hiragana and katakana. Kanji characters are morphographic in nature and are of Chinese origin. In contemporary Japanese, kanji characters represent not only content words originally borrowed from Chinese, but also compounds created by the Japanese themselves and native Japanese vocabulary. Two-kanji compounds are extremely common, making up approximately 70 percent of the entries in a typical Japanese with regular and rule-governed relationship. Of the two sets of kana, hiragana are cursive in shape and are used as grammatical morphemes as well as for some content words, whereas katakana are used simultaneously in written Japanese texts. In addition, romaji, based on the Roman alphabet, is also used for Japanese words and sentences, independently from the other three scripts, but its use is extremely limited. The eight papers in this Special Issue all discuss various aspects of cognitive processing of Japanese morphemes and words presented in kanji, hiragana and katakana.

Tamaoka and Hatsuzuka investigated the way in which the activation of semantic representations at the morpheme level affects the processing of two-kanji compound words. Three types of two-kanji compound words were used as stimulus items: Words consisting of two kanji representing similar concepts, and words consisting of two closely bound kanji. Words consisting of kanji representing opposite concepts were processed slower for lexical decision than words with kanji representing similar concepts, both of which were, furthermore, processed more slowly for lexical decision and naming

than the control compound words. Because kanji morphemes of opposite and similar concepts are semantically activated both as morpheme units and compound word units, semantic representations of the two morphemes and the compound word which they create compete with each other at the concept level; and the competition slows down lexical decision and possibly naming of the compound word.

Historically, kanji characters were considered 'logographic' in nature and their phonological aspects were often ignored in earlier studies. However, approximately half of commonly used kanji in the Japanese language contains phonological elements. Many kanji characters are also constructed from multiple constituents, with some indicating speech-sound and some suggesting meaning. Thus, the phonological aspects, as well as the orthographic and semantic aspects, must have an important function in kanji processing.

In four converging experiments using a radical migration technique, *Saito, Masuda and Kawakami* examined the interactive effects of phonological information based on the figurative or figural similarity of whole word and different combinations of subword units of radicals on the recognition of kanji characters. Their results show that automatic recognition of kanji is achieved through the mutual activation of information of whole characters and their constituent radicals. Saito et al. suggest that these findings can be explained by their 'companion-activation model (CAM)' within an interactive-activation framework.

In terms of the multi-levels of processing Japanese kanji, there are On-reading (of Chinese origin) and Kun-reading (of Japanese origin) for these characters. The paper by *Wydell* addresses some of the issues. Using computational modeling, Wydell investigated the subword level and the whole-word level contribution to the computation of phonology in the processing of two-kanji compound words. Her study suggests that the computation of the phonology of kanji words was affected by the structural differences between On-reading and Kun-reading of the kanji compound words. The effects of On- and Kun-readings for the phonological processing of kanji compound words provide insight into human cognitive processing of kanji characters.

How clearly could native Japanese speakers distinguish between On- and Kun-readings of kanji characters? This issue was studied by *Hirose*. From his questionnaires containing a list of kanji characters and their associated readings, Hirose suggests that, to some degree, the phonological boundary of On- and Kun-readings is not as clear as Japanese dictionaries indicate with regard to the sound of each kanji. Japanese native speakers utilized a processing strategy concerned with the degree of a single-kanji semantic independence

to decide whether or not the pronunciation of a kanji character presented in the list calls for a On- or a Kun-reading.

In terms of kana scripts, katakana is mainly used for loan words, typically those from languages with phonemic writing systems and proper nouns from foreign countries and some onomatopoeic and mimetic words. *Hino, Lupker, Sears and Ogawa* investigated the effects of polysemy or multiple meanings of a single word as a function of word frequency for loan words presented in katakana script. These researchers found the effects of polysemy on the performance of both their naming and lexical decision tasks while word frequency had no effect on the performance of vocalization. These results are discussed by Hino et al. within the framework of the dual-route and parallel distributed processing (PDP) models.

Yamada compared the differences in the processing of words (both grammatical nouns and verbs) presented in hiragana and kanji. In his experiments, words presented in hiragana were named faster than the same words shown in kanji. This trend was reversed when the subjects had to translate them into English: Words in kanji were translated faster than those in hiragana. These results suggest that words in hiragana were more closely related to phonology while words in kanji were more closely related to meaning. Yamada's findings are congruent with the linguistic characteristics of Japanese kanji and also with commonly held notions tested psychologically that kanji characters are accessed faster because of their semantic nature than the phonologically based hiragana.

The overall phonological function in processing Japanese is reviewed by *Kinoshita*. As a long-time resident of Australia and a well-balanced bilingual (Japanese and English), she begins with an intuitive statement of: "I do not seem to rely on 'inner speech' as much when reading text in Japanese relative to English". Kinoshita suggests that one main reason for this tendency might be the greater visual discriminability, and also less importance in word order, in Japanese than in English. Since phonology plays an important role in the maintenance and processing of information in working memory, the phonological function in reading Japanese text might be reduced. One way to examine the degree of phonological involvement might be well designed cross-linguistic studies in processing Japanese and English sentences (see, for example, MacWhinney & Bates 1989).

Moving from lexical access, *Hatta, Kawakami and Tamaoka* studied the writing behavior of native Japanese speakers and Australian university students learning Japanese. These researchers found that for native Japanese speakers kanji writing errors occurred more frequently in relation to kanji phonology than orthographic patterns or semantic factors. This finding of strong phonological involvement in processing kanji by native Japanese, how-

ever, was not observed with Australian college students learning Japanese. These latter students tended to make more orthographic errors than those arising from Japanese phonology. These differential types of errors in writing kanji suggest possible results from the subjects' differential levels of kanji knowledge.

Further research issues

In terms of processing lexical items in either Chinese and Japanese many of the research papers in this Special Issue are predicated on the interactive-activation model (e.g., McClelland 1987). According to this framework, the lexicon is made up of different levels of units or nodes arranged according to features, sublexical units, characters and words and these multi-levels exert facilitative and inhibitory effects in processing. Lexical decision and naming of these units are affected by the strength of the phonologic-orthographic links.

There are other research issues not directly dealt with by the papers in the two sections. One such issue is the effective use of morphological and morphographical constituents for Chinese character recognition (e.g., Chen, Allport & Marshall 1996). A related issue is the impact of submorphemic information such as radical status and frequency on processing Chinese characters (e.g., Taft & Zhu 1997). And yet another issue is the locus of frequency effects in lexical decision and naming of Chinese characters and pseudo characters (e.g., Liu, Wu & Chou 1996). All these examples pertain to the assignment of units in the orthography-to-phonology correspondence for reasonably accurate pronunciation of Chinese characters.

There are similar research questions relating to the organization of the lexicon in Japanese such as the inter-facilitation of single and compound kanji characters with their On- and Kun-reading (e.g., Morton, Sasanuma, Patterson & Sakuma 1992). These issues are addressed directly by some of the authors in this Volume. The question of reading kanji without semantics is another intriguing one. The developmental study of three Japanese patients with dementia by Sasanuma, Sakuma and Kitano (1992) shows that there may be multiple levels operating in processing kanji and that there may be an independent orthography-to-phonology transcoding process. This line of cognitive neuropsychological study finds a parallel with the study of English patients showing loss of word meaning and a surface alexic pattern of reading performance (Patterson & Hodges 1992).

The papers in this Special Issue offer a rich array of concepts, data and research findings in our quest to understand the cognitive processing of the morphosyllabic Chinese and the Japanese syllabary with its kanji, hiragana

and katakana scripts. There is a great deal for researchers to 'read, mark, learn and inwardly digest', as enjoined by the Book of Common Prayer.

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