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AUTHOR Tzeng, Ovid J. L.
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ABSTRACT

Recent research on Chinese orthography is reviewed in a discussion of the relationship between orthographic symbols and reading processes. Specifically, these issues are addressed with relation to research findings: the difficulty of learning Chinese logographs, particularly with regard to learning disabilities and biliteracy; whether reading in Chinese requires an enhanced visual memory; whether the recoding process is required in skilled reading of Chinese, because logographs do not contain information about pronunciation; the need for phonological awareness in order to read Chinese script; and whether reading in Chinese requires greater right brain hemisphere processing. Contains 93 references. (MSE)

CHINESE ORTHOGRAPHY AND READING: A CLARIFICATION

OVID J.L. TZENG

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Ovid J. L. Tzeng

Writing systems have been qualified as logographic, syllabic or alphabetic according to the morphemic, syllabic or phonemic representation level of the speech (Hung and Tzeng 1981). Among the many writing systems existing in the world today, Chinese logographs are unique in that their relationship with the spoken language they transcribe is rather opaque. This relationship can be described as morphosyllabic in nature. However, the logographs and syllables do not have a one-to-one correspondence: the same syllable may be represented by different logographs with different meanings. The number of Chinese logographs has expanded to tens of thousands, and they are complex in configuration (Hung and Tzeng 1981, Tzeng and Wang 1983, Wang 1981). In his latest book on the developments of various writing systems, DeFrancis (1989) concludes, after a critical evaluation of the functional usefulness of most scripts, that a fully developed writing system has to be speech based. Interestingly, under such a conceptualization, Chinese writing system is very much sound-based and accordingly, its reading comprehension depends on the success of recovering its morphosyllabic representation. As we will see later, indeed, experimental results of recent psycholinguistic and neurolinguistic studies on reading Chinese are very much consistent with such an analysis (Tzeng, Hung and Lee 1991).

There is another unique aspect of Chinese logographs that needs to be mentioned. Centuries ago, these logographs were adopted by the Korean, the Japanese, and the Vietnamese to become their respective national writing systems. The sound systems of these languages are quite different from spoken Chinese, and there were major problems in adopting the Chinese writing system to transcribe them. Today, North Korea and Vietnam have dropped the use of Chinese logographs altogether and opted for an alphabetic system. However, South Korea and Japan have maintained them, and created sound-based systems (the Hangul alphabet for Korean and Kana syllabaries for Japanese) to overcome the problem of mismatch between the writing system and the sound system. Let us take a closer look at the Japanese case.

The origin of the Japanese spoken language is quite different from that of Chinese. The former evolved from the Altaic family of languages, which includes Turkish and Mongolian (Miller 1980). The latter, however, is not part of the Altaic 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 different pronunciations of the Kanji (the borrowed Chinese logographs) characters--a Japanese pronunciation and an approximation of the Chinese pronunciation. In addition, due to syntactic requirements, they have developed two syllable-based scripts in order to be able to represent function words and loan words. These are called Kana script in general, and the hiragana and katakana syllabaries specifically. Nowadays an ordinary Japanese text contains all three scripts in their distinctive styles.

For most Indo-European languages, the writing system, patterned after that of the Greeks, evolved to an alphabetic script, with the number of written symbols extensively reduced. A full alphabet, marking vowel as well as consonant phonemes, developed over a period of about 200 years during the first millennium B.C. in Greece (Kroeber 1948). The transition from the syllabic to the alphabetic system marked a gigantic jump with respect to the script/speech relationship. In fact, the development of vowel letters, which forms the basis of the analytical principle of an alphabetic system, has been characterized as something of an accident rather than a conscious insight (Gleitman and Rozin 1977). As a sound-writing script, an alphabetic system maps onto speech at the level of the phoneme, a linguistic unit smaller than the syllable but larger than an articulatory feature.

As we look back at these historical changes, we see that the evolution of writing seems to have taken a single direction: at every advance, the number of symbols in the script decreases, and as a direct consequence the abstractness of the relation between script and meaning increases and the link between graphemes and phonemes becomes clearer. This pattern of development seems to parallel the general trend of cognitive development in children and thus may have important implications for beginning readers of different orthographies. One of the major activities in learning to read is exploring the correspondence between the written script and the spoken language (Tzeng and Singer 1981). Since the script/speech relations in different orthographies tap into different levels of speech perception, and since the size of the minimal character set required for transcribing the entire speech segments in a language depends on such mapping relations, these unique historical developments provide ample opportunity to study the effects of orthographic variations on visual information processing within and across languages, and with respect to both skilled and beginning readers. A question of psychological interest concerns the extent to which different orthographies undergo similar (or different) processing. Only a correct description of the nature of symbols can help us to unravel the tangled story of success as well as failure in learning to read different scripts. Precise characterization of and closer examination into each type of the ever existing scripts in terms of the depth of script/speech mapping is necessary for any theoretical analysis of reading processes.

With respect to the question of linguistic relativity due to the variations in the orthographic structure, the Chinese language has been condemned as well as appraised, all because of its many unique properties. For example, in the 19th century August Schleicher proposed that "isolating" languages, such as Chinese, which used simple elements and were thus more "primitive" than" agglutinating" languages, which build their words from distinct forms. In contrast, as Wang has cogently pointed out, "Perhaps it is this structural simplicity of the language that moved the anthropologist and linguist Edward Sapir to characterize it as 'soberly logical'." (Wang 1973).

It is also true that more than any other writing system, the Chinese, with its non-alphabetic nature, has been besieged by "China experts" advancing potentially

embarrassing notions. Most of these self-proclaimed experts are merely harmless drudges in the grip of a private theory. But there also were Leibniz and many other outstanding thinkers of the 17th and 18th centuries, who were much taken by the idea of creating a universal language based upon "scientific" principles similar to those which they thought underlay the Chinese system of writing (DeFrancis 1989). Such an idea persists even among modern-day scholars of high academic standing. Thus, for the well-known anthropologist Margaret Mead, the Arabic numeral system provides a partial model for a universal language of science, and the Chinese system "the most complete model" (Mead and Modley 1968:62). The enthusiasm was fueled by a research report in *Science* which showed that disabled readers of English in a Philadelphia elementary school were successfully taught to read English represented by Chinese characters (Rozin, Portsiky, and Sotsky 1971).

The results of the Philadelphia study and their implications have been disputed over the last two decades and the excitement of a possible "supreme orthography" dwindles down quite a bit after the observation of a null-finding from a renowned large scale study which involved three countries across three different writing systems (Stevenson 1984). However, curiosity about the on-line reading processes from a comparative perspective continues to persist among cognitive psychologists who are interested in building a "universal" theory of reading (Hung, Tzeng, Lee, and Chang 1994, Seidenberg 1985). The new debates center around topics such as the scriptal effects on the nature of reading disability, on modeling word recognition and naming processes, on the relationship between the phonemic awareness and learning to read, and on the development of higher cortical functions. A rigorous research methodology adopted from the experimental psychology tradition and a processing-oriented theorization imported from the emerging cognitive neuro-science program have helped to get rid of some of the wild notions about reading Chinese. In the following, I will review results from studies of the new approach under topics which are most relevant to our concern here.

Are Chinese Logographs Difficult to Learn?

One of the most popular statements made against the Chinese writing system is that, in spite of the beautiful shape and configuration of its logographic symbols, it is a very difficult writing system to learn for beginning readers. The belief in such a difficulty centers on the fear that the vast number of logographic symbols requires a tremendous amount of mental capacity for their mastery. A curious thing is that everyone seems to take this belief for granted and no one seems to be concerned with whether it is justified. There has never been a comparative study which examines the relative rates of reading acquisition in Chinese and another non-Chinese script (e.g. English). On what basis, then, can one make the claim that the Chinese is more difficult for learning to read? At a closer look, it can be shown that the specific negative statement made against the Chinese writing system is totally unfounded at both the theoretical and empirical levels.

Park and Arbuckle (1977) directly compared memory for words represented by Chinese logographs with memory for those same words represented in an alphabetic script (i.e. Korean Hangul letters). They found that the words were recognized and recalled more successfully when represented by logographs than when presented in alphabetic script. A similar conclusion was reached by Steinberg and Yamada (1979) in an experiment which compared the relative ease of learning Kanji and Kana symbols. They had 42 3- and 4-year-old children each learned a 4-item list for 10 trials with a paired-associate learning paradigm. The stimuli were 2 Kanji logographs and 2 Kana symbols and each of the four symbols were paired with its spoken name. That is, the subject's task was to learn to "recognize" the stimulus and supply its appropriate spoken name. The results showed that for the Kanji logographs, 37% were learned within 3 trials while most Kana were not learned at all even at the end of the 10th trial. Thus, young children seemed to learn Kanji faster than Kana script despite its perceptual complexity.

Of course, we cannot, and should not, take the above demonstration of the superiority of the logographic script too seriously either, for these studies are not without criticisms with respect to their methodology (see Tzeng and Singer 1978-79). Nevertheless, the point I want to emphasized here is this: No empirical evidence has ever been provided to support the proposition that the Chinese logographs are difficult to learn relative to other scripts! If anything, the results of those cross-script memory experiments, usually point to the direction favoring the Chinese logographs.

At a more extreme level, we can also take a serious look at the proportion of reading disabled children across different writing systems. In there, the issue of concern takes an ironical twist: In the literature on reading disability, the Chinese writing system has been appraised rather than condemned! That is, it has been suggested, with survey data as supporting evidence, that the occurrence of reading disability is extremely rare in the writing systems which use the Chinese logographs as their basic building blocks (Makita 1968, Kao 1978). Since the early 1980s, several groups of multi-disciplinary research teams, usually consisting of experimental psychologists, educators, speech pathologists, pediatric neurologists, and school psychologists, have carried out a series of comparative studies to test the validity of the commonly held belief that there are fewer incidences of reading disabilities in Chinese and Japanese.

The first serious attempt was launched in 1982 by Stevenson, Stigler, William, Lee, Hsu, and Kitamura. To achieve their research goal in three different languages (i.e. Chinese, Japanese, and English) and cultural environments, three compatible sets of individually administered and standardized Michigan Tests, which comprised graded reading tests and ten cognitive tasks, were constructed. They found that 6.3% children in Minneapolis (U.S.A), 7.5% in Taipei (Taiwan), and 5.4% in Sendai (Japan) could be classified as reading disability students. Thus, they concluded: (1) similar cognitive abilities were required to read all three languages, (2) visuospatial and perceptual abilities were not more involved in reading Chinese

and Japanese than in reading English, and finally, (3) reading disability was as common in the two oriental countries as in the United States.

Taking advantage of the bi-literacy requirement in Singapore elementary schools, another group of investigators (Hung, Tzeng, Lee, and Chang 1994) examined the reading performance of Chinese-English bilingual children at the entry level. Their findings and conclusion were in general consistent with those of the Stevenson's group. Furthermore, Chang, Hung and Tzeng (1992) have done an error analysis of oral reading protocols of Chinese monolingual normal as well as disabled readers. A detailed analysis led them to the conclusion that most disabled readers of Chinese were not hampered by the learning of logographic symbols per se; rather, their problem lies in their inability to correctly segment the string of evenly spaced characters into appropriate word units. Why this should be so still remains an open question and future research has tc pinpoint the exact nature of the word segmentation difficulty in reading Chinese from a theoretical perspective. Nevertheless, it is quite clear that once again we have to point out that there is no reason at all for the Chinese logographs to be casted as a difficult script to be learned.

Does Reading Chinese Require an Enhanced Visual Memory?

Studies in English have repeatedly demonstrated that reading ability is related to phonological memory and not to visuospatial memory (Baddeley 1986, Liberman, Mann, Shankweiler, and Werfelman 1982, Mann and Liberman 1984, Shankweiler and Crain 1986). Conventional wisdom says that in an logographic script such as Chinese characters (Hanji) the reverse should be expected because of the unique visuospatial arrangement in the printed symbols. But so far no direct evidence has been provided for or against such an expectation with respect to the reading processes of the Chinese writing system. The only study which has somewhat addressed this issue was conducted by Mann (1986). She tested 100 Japanese second graders on visuospatial memory for nonsense figures as well as phonological memory for Japanese nonsense words using a recurring recognition paradigm. She found that good readers performed better on both tasks compared to the poor readers and that there was a low but significant correlation between reading ability and phonological memory for nonsense words. In addition, the results showed that visuospatial memory for nonsense figures was significantly correlated with reading Kanji (adopted from Chinese Hanji) but not Kana (a sound-based script with each unit representing a syllable or mora).

Mann's (1986) data with the Japanese readers are intriguing, in particular the correlation between their visuospatial memory for nonsense figures and their reading performance with the Kanji characters. To explore these findings further, since 1988 two systematic studies have been conducted among monolingual and bilingual Chinese children to examine the relationship among reading ability/disability and linguistic and non-linguistic memory. One of the tasks for non-linguistic memory was adopted from Mann's (1986) study in which the nonsense

figures were formed by abstract and nonsense patterns of lines and curves presented in a recurring visual recognition research paradigm (Mann 1986, Chang et al. 1992). Among the monolingual readers, the results showed that the disabled readers performed equally well as their normal achieving peers in both non-linguistic memory tasks, such as recognizing nonsense figures and reproducing geometric designs from memory. However, the disabled readers performed significantly lower than their peers in tasks requiring them to immediately recall *in verbatim* a sequence of digits and unrelated words. The literature shows that an inability to activate phonetic recoding, or representation, in order to maintain linguistic information in working memory is thought to be related to children with reading disabilities in English language (Brady and Shankweiler 1991, Leong 1991, Liberman et al. 1982, Shankweiler and Crain 1986, Torgesen 1988, Wagner and Torgesen 1987). Based on the comparative study between two groups of Chinese beginning readers, the results show that Chinese disabled readers performed significantly lower, when compared with their normal achieving peers, in processing language related elements such as digits and unrelated words (Chang et al. 1992).

Regression analysis of the scores obtained from bilingual children in Singapore suggests that phonological memory, measured through recurring auditory recognition of nonsense syllables, contributed towards prediction of English reading scores but not Chinese reading scores. Visuospatial memory, on the other hand, was not a significant factor in predicting reading in either language. Rote memory for shapes did not appear to be an important factor in reading Chinese logographs. Contrary to conventional wisdom, visuospatial memory ability could not explain the phenomenon of reading disability in both languages.

The results of a recent study in our laboratory tell a more revealing story. We were able to trace 16 students who were labeled "reading disabled" four years ago in the study conducted by Chang et al. (1992). These RD students had been assigned to a specially set-up resource classroom where they received intensive remedial programs in order to improve their reading skills. Among them, eleven had made satisfactory progress and were re-enrolled in the regular classroom. The remaining five, however, seemed to get nowhere even after the intensive training; they were probably all RD students in every sense of the word. Various experimental tests tapping on different cognitive skills were administered to these five RD children and to their peers with good reading skills. We found that on tasks that demanded the visuospatial memory ability, these RD children performed as well as their control group. They also showed no deficit in the memory for environmental sounds (i.e. wind blowing, car braking, whistling, etc.). Indeed, their cognitive deficit only showed up in speech-related tasks!

We shall discuss the issue of phonological processing in the next section. Here our concern is with the relationship between the visuospatial ability and learning to read Chinese logographs. Our conclusion is once again very clear: There is none! This is not to deny the importance of visuospatial processing during reading. Of course, it has to be an important component, because undoubtedly the visual sensory registration is the first stage of processing the printed symbols. However,

there is no need to propose a special requirement for enhancing the visuospatial ability in order to learn to read the Chinese logographic system.

Does Skilled Reading of Chinese Not Require the Speech Recoding Process?

Fluent readers can read faster than they can talk, but for a child just learning to read, the opposite is usually true because every word has to be sounded out in order to get at the meaning. At some point during the process of acquiring reading skills, the transformation of visual code into speech code becomes automatic via some non-lexical symbol-sound correspondence rules, or becomes unnecessary altogether (the latter view has generally been referred to as the direct access hypothesis). In recent years, studies of word recognition in an alphabetic script like English have been dominated by concern over the nature of the code that allows the reader to go from print to meaning, a process called lexical access (Adams 1990).

Almost twenty years ago, when experimental psychologists started to launch their first series of attacks on reading from the perspective of information processing, using reaction time as the dependent measure, a number of investigators held the view that phonological recoding was a necessary preliminary to lexical access (Gough 1972, Gough and Cosky 1977, Rubenstein, Lewis, and Rubenstein 1971). A considerable amount of evidence was collected to support the phonological recoding hypothesis. However, other investigators were accumulating abundant evidence to support the direct access hypothesis. It is now clear from both the experimental and neuropsychological literature that, for a large number of words, phonological recoding for the purpose of lexical access is not necessary; in fact, some form of orthographic or visual code is sufficient for the purpose of getting meaning from print (Henderson 1982, Hung and Tzeng 1981, McCusker, Hillenger and Bias 1981, Saffran and Marin 1977, Seidenberg 1985).

Adding Chinese logographs into the picture seems to complicate, rather than clarify, the issue. Early supporters of the direct access hypothesis always used the example of reading Chinese to reinforce their argument. The argument goes like this: Because Chinese logographs do not contain information about pronunciation, people must be able to read without speech recoding.

However, this statement is not exactly correct. First, Chinese logographs consist of a majority of phonograms that at times do give clues to pronunciation. Thus, with the ability to pronounce a limited number of basic logographs, and knowledge of orthographic rules in the construction of logographs, readers of Chinese can in fact make reasonably successful guesses about how to pronounce logographs that share the same phonetic component, even those that they have never encountered before (Zhou 1978). The procedure involved in this type of grapheme-sound conversion is of course very different from that involved in the GPC (grapheme-phoneme conversion) rules advocated by Coltheart (1980). But it is similar to Glushko's (1979) activation-synthesis model of the generation of phonological codes. Indeed, such a procedure of generating phonological codes by

analogy was proposed by Tzeng (1981) as one of two mechanisms in speech recoding, and was recently thought to be used by fluent readers of English for most words (Kay and Marcel 1981, Seidenberg 1985). Empirical evidence for the operation of this type of speech recoding in reading Chinese has been provided by Fang, Horng and Tzeng (1986) and by Lien (1985). Second, the Chinese writing system also makes it very clear that we cannot assume a one-to-one correspondence with respect to se.. antics between a word in print and a meaning in the mental lexicon. Single logographs are often recombined to make up new words; hence, there is nothing in the lexicon to be accessed. Meanings of words become available through the reference back to phonology and contexts. In this sense, it is rather difficult, if not impossible, to conceive of the access of lexicon via some orthographic or visual configurational cues. To a lesser degree this may also be true with respect to English orthography.

Reading should not be equated with the lexical access of a single word; rather, it should be regarded as a series of more general linguistic activities such as iconic scanning and storage, lexical retrieval, short-term retention, syntactic parsing at both macro- and micro-levels (Kintsch and Van Dijk 1978), and semantic integration over the entire discourse. This kind of conceptualization immediately questions the validity of the view that reading logographs involves no grapheme-phonology translation.

Thus, despite the bias towards direct grapheme-to-semantic processing, logographs may also activate phonological recoding processes. Erickson, Mattingly, and Turvey (1977) found increased errors in an immediate memory task when Kanji characters were phonologically 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.

One implication to be drawn from all of these findings is that phonological recoding is just one of the strategies for obtaining access to meaning, rather than an obligatory stage. There are at least two major ways in which such a recoding process is important.

First, in blending the individual letters (or logographs) of words, the phonological recoding of the individual letter (or logograph) sound can plausibly be argued to be an important intervening stage, at least for children learning to read. A second way in which phonological recoding may be involved in reading is concerned with the question of whether fluent readers need to phonologically recode printed materials or are assisted by doing so. In this latter view the phonological recoding is regarded as a general strategy of human information processing, and thus, the orthographic difference in the printed materials becomes less important (Tzeng et al. 1977).

Is Phonological Awareness Not Essential for Learning to Read the Chinese Script?

Phonological awareness is the ability to recognize the internal structure of spoken words; it is usually assessed by testing the subjects' ability to isolate and manipulate individual phonemic segments in words. Much evidence is now available to suggest that awareness of the phonological constituents of words is an important prerequisite to fluent reading. This evidence comes from studies in several different alphabetic scripts which have shown that this awareness is predictive of reading success in young children (Adams 1990, Brady and Shankweiler 1991). No similar studies have yet been conducted in children learning to read logographic scripts.

Metalinguistic deficiencies in the phonological domain have also been demonstrated in adults with difficulty attaining literacy in alphabetic scripts (Morais, Carry, Alegria, and Bertelson 1979). However, a study in China found that adults literate only in traditional Chinese characters could not add or delete individual consonants in spoken Chinese words whereas adults literate in alphabetic Chinese as well as Chinese characters could (Read, Zhang, Nie, and Ding 1986). This study suggested that phonological skills involved in "segmentation" develop in the process of learning an alphabetic script, but not in learning a logographic script.

While there has been much evidence for the requirement of phonological recoding in fluent reading of Chinese (Tzeng et al. 1977), arguments against the idea that phonemic awareness may play a role in learning to read Chinese are still strong. This issue was examined in depth to compare the role of phonemic awareness in reading Chinese and English by studying two groups of Singapore beginning readers who simultaneously learned to read and write both Chinese and English (Lee et al. 1991). The findings of the first study showed that among the English-dominant bilingual children, their performance on a phonemic segmentation task correlated significantly with reading scores on both English and Chinese. It also was a significant predictor of reading ability in both languages. The findings of the second study among a group of children who were not dominant in English provided an interesting contrast. The relationship between reading achievement in English and phonemic awareness remained strong, whereas the relationship between reading Chinese and phonemic awareness became marginal. Together, these results suggest that it is alphabetic instruction, rather than maturation per se, that is responsible for the improvement in phonemic awareness occurring around the age children learn to read (Lee et al. 1991).

These two studies confirm the findings of other researchers who have studied children learning to read alphabetic scripts that phonemic awareness is important in reading English. However, the same issue is far more complex in the case of reading Chinese logographs. In our first study among the English dominant group, it is likely that these children gain the ability for analyzing the internal structure of

speech sounds from learning to read English and in turn, use this ability to explore the phonological principles of Chinese logographs or characters.

It is well known that more than 85% of Chinese characters are phonograms. Each phonogram can be decomposed into two graphemic parts, a significate radical to indicate a general semantic category, and a phonetic component to give a clue to its pronunciation. Recent experiments by Tzeng and his associates have provided strong evidence that Chinese fluent adult readers take advantage of the generic properties of phonograms for decoding newly encountered Chinese characters. If this is the basic skill underlying the proficient reading of Chinese text, then it is likely that children who get access to this orthographic knowledge will be better able to expand their character size. Such a phenomenon has indeed been observed among Chinese monolingual beginning readers. Particularly, the speed in "character" acquisition among the disabled readers was impressive as they progressed through primary to intermediate grade levels (Chang et al. 1992). Hence, the unique formations of Chinese characters likely would not be the obstacle for reading and literacy development in Chinese logographic writing system. However, the Chinese "word" acquisition among the disabled readers lagged behind their normal achieving peers, as was evident in their reading error patterns.

In order to understand this line of research and the results obtained in the bilingual studies, the major issues are summarized as follows. First, the exploration of phonological clues from the Chinese characters is useful for reading. However, this presupposes that there is indeed phonological information available in the script, albeit some Chinese characters are more difficult to decipher. However, the connection between orthography and phonology is very important to all beginning readers. Early on Chinese children would have been exposed to some of the commonly used reading strategies to sound out unknown words. For example, if two graphic components are side by side, the strategy is to read the one on either side. If the character is formed by layers, the strategy is to try the sound clue presented in the center.

Second, the exploration of the script-speech, or orthography-phonology, relationship, though useful, is not the required way to learn to read Chinese because of the morphological differences. However, this is not to deny the importance of the role of phonological memory in the syntactic parsing and comprehension processes in which verbal elements are required to be held long enough to process information. On the contrary, since there is little pre-lexical phonological information available for the Chinese beginning readers to decipher logographs as opposed to sound-based alphabets, beginning readers have to rely solely on the post-lexical phonology, such as a learned pronunciation for each logograph or character, in order to convert the printed symbols into their phonological representation in memory. In a review of the literature, Adams (1990) concluded that such an automatic phonological processing ability is an important asset to all experienced readers. This may explain why the ability of phonological memory correlates with reading ability in Chinese.

Third and perhaps most importantly, the finding that the way a Chinese beginning reader acquires his/her reading skills can be influenced by the instructional environment may hold the key for the differentiation of alphabetic and non-alphabetic scripts. For students learning to read an alphabetic script, a pure graphic-based strategy, independent of phonology is not possible, whereas for students learning to read Chinese, which is morphosyllabic in nature, either the phonological or the orthographic strategy may predominate. Of course, as long as there is some phonological information embedded in the characters, there will be some overlap of these two options. It is suggested that for Chinese readers, the choice of either option depends a great deal upon the instructional environment, as revealed in two of these interrelated studies conducted in Singapore. Such a conceptualization may help to resolve much controversy on the necessity of "speech recoding" (e.g. converting the visual image of print into its phonological representation) in learning to read Chinese (cf. Tzeng and Hung 1988, Leong 1991).

Does Reading Chinese Involve a Greater Right Hemispheric Processing?

Throughout the history of hemispheric specialization research, there has been speculation about the possibility that the functional organization of a literate brain may be related to the type of written script one has learned to read. From Dejerine (1891) to Hinschelwood (1917), and from Luria (1970), Hecaen and Kremin (1976), Benson and Geschwind (1969), Zaidel and Peters (1981), evidence has been provided to show a selective sparing of reading one type of script despite severe impairments in the reading of other scripts in bilingual aphasic patients (for a more detailed review, see Hasuike, Tzeng and Hung 1986). Data from these bilingual studies are illuminating. However, they suffer from the lack of appropriate control of the degree of impairment of the spoken language. In this respect, recent findings of selective impairment in the reading of Kanji and Kana scripts by Japanese aphasic patients within a single spoken language have strengthened the hypothesis of the scriptal effect on cerebral organization (Hung and Tzeng 1981, Sasanuma 1980).

It should be noted that the finding of selective impairment in the reading of the two types of Japanese script does not necessarily implicate a right hemispheric involvement for processing Kanji. In fact, Sasanuma and her associates (Sasanuma 1975, 1980, Sasanuma and Fujimura 1971, Tatsumi, Itoh, Konno, Sasanuma and Fujisaki 1982) have argued for a differential disruption of language due to localized lesions in the left hemisphere, rather than postulating a dichotomy of right and left hemispheric processing for Kanji and Kana scripts. According to Hasuike et al. (1986), before the mid-1970s, there seemed to be no disagreement about the role of the left hemisphere for processing Chinese logographs. However, in 1977 two papers attracted much attention because both showed some evidence for right hemispheric involvement in reading Chinese logographs.

The first study was by Hatta (1977), whose results showed that native Japanese readers identified singly presented Kanji characters better when they were presented

in the left visual field than in the right visual field, implying a stronger right hemispheric involvement. In previous studies (Hirata and Osaka 1967), native Japanese readers had showed the reverse lateralization pattern in identifying Kana symbols, implying a left hemispheric involvement in the processing of such sound-based script. Hatta's new finding was in accord with results obtained by Sasanuma, Itoh, Mori and Kobayashi (1977), in which nonsensical two-character Kana and Kanji characters were presented to native Japanese readers for identification. They found a significant right visual field superiority for the recognition of Kana symbols and a non-significant left visual field superiority for Kanji characters. Results from these two studies have often been cited to give evidence for right hemispheric involvement in the processing of Kanji logographs.

However, this seemingly clear picture begins to look very messy when one examines data from studies using Chinese readers. Visual hemifield experiments with Chinese subjects (Hardyck, Tzeng, and Wang 1977, 1978; Kershner and Jeng 1972) clearly showed a right visual field (left hemisphere) superiority for processing Chinese logographs. The discrepancy between the Japanese and Chinese results in these studies is curious. One possible interpretation is that Japanese readers process Kanji characters differently from the way Chinese readers process Chinese logographs, perhaps because of some unknown interaction between Kanji and Kana. Put another way, the Japanese not only borrowed the Chinese logographs, but also developed a different brain function in order to read them--hardly a plausible interpretation!

The major problem with visual hemifield experiments using a tachistoscopic procedure is the lack of control over the variables that could affect the results. Paradis, Hagiwara and Hildebrandt (1985) discuss such factors related to the nature of the stimulus, the presentation conditions, the task demands, the response, and the subjects, and note that in most studies the familiarity, concreteness, and types of logographs are often not specified, let alone be controlled. Thus, discrepancies could easily arise because of procedural differences. Tzeng, Hung, Cotton and Wang (1979) manipulated the number of logographs in two experiments, and found a left visual field superiority for recognition of single logographs and a right visual field superiority for two-logograph words. Hasuike et al. (1986) went a step further, in carrying out an extensive comparison among all relevant experiments up to 1985. They identified the stimulus exposure duration as the key variable because the left visual field's (right hemisphere) superiority was obtained only in those studies in which exposure duration was less than 50 msec. This makes sense: short exposure duration produces an incomplete visual image with a very low spatial resolution, and the literature has shown that the right hemisphere is adept in perceiving the relationship between these fragmentary components and the whole configuration (Sergent 1983). When the stimulus is presented for a longer exposure the spatial resolution is better, and under such conditions the left hemisphere seems to take over, especially when the task requires further linguistic analysis. It should be concluded then that there is very little evidence, from either experimental or clinical studies, to suggest a stronger right hemispheric involvement in the linguistic analysis of Chinese logographs. In fact, recent experimental evidence shows a very

left hemispheric dominance in the processing of Chinese characters (see Bellugi, Tzeng, Klima and Fok 1990 for a critical examination of this issue).

Concluding Remarks

As we all know, Chinese is one of the written languages first recorded in human history. Fragmentary recordings date back more than 4,000 years, but real comprehensive recording came about only in the writings of the ancient sages, particularly the so-called confucian Classics, that appeared 3,000 to 2,500 years ago, followed by the even more extensive writings of the philosophers or latter-day sages, during the so-called Warring States period between 2,500 and 2,200 years ago. The confucian Classics, together with the writings of some of the philosophers, played a very important role in the formation of the Chinese civilization, perhaps a much greater role than that of the Bible for European civilization. It has been said that the Chinese civilization is like a crown shining through the history of humankind. It has further been said that the Chinese writing system is like a pearl on top of the crown. Interestingly but almost unbelievably, while the Egyptian hieroglyphs and Babylonian cuneiform can only be found in museums of history, modern day Chinese readers are reading exactly the same logographs as those read by their ancestors two thousand years ago.

In a sense, through the same medium, the Chinese people live simultaneously both in the present and in the past. It is no wonder that Chinese scholars are so proud of their writing system.

However, as we have shown in reviewing the current status of the Chinese writing system from the perspective of scientific research, widespread misconceptions about the nature of Chinese logographs have led to a lot of wild guesses about the psychological realities of reading Chinese. We have also witnessed an outpouring of incorrect claims made by famous neurologists and psychologists concerning the brain basis of reading Chinese. Of course, we should be delighted for the possibility that the Chinese language, due to its various unique features, has been considered to be an important language for a possible theoretical breakthrough in our understanding of reading behavior. But it is essential that every speculation about its psycholinguistic status has solid empirical foundations.

In this paper, we have carefully reviewed several issues pertinent to the learning and reading of written Chinese. Our conclusions are not much different from those reached a decade ago by Hung and Tzeng (1981), except that over the years, many minute details of the underlying operations have been identified and substantiated in experiments on a variety of cognitive tasks and with different subject populations (i.e. beginning as well as skilled readers, mono- as well as bilingual readers, RD students, and aphasic patients). It is clear that, despite the seemingly very different script/speech relationships embedded in different written languages, there is much commonality in the process of extracting meanings from print. The important question to be asked about reading, therefore, is not "what" are the differences?, but

rather, we should ask why it should be that there remains so much commonality in the psycholinguistic processing across the perceptually different scripts!

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References

Adams, M.J. (1990). *Beginning to read: Learning and thinking about print.* Cambridge, MA: MIT Press.

Baddeley, A.D. (1986). *Working Memory.* Oxford: Clarendon.

Benson, D.F. & Geschwind, N. (1969). The alexia. In P.U. Vinkel & G.W. Bruyn (eds.), *Handbook of Clinical Neurology, Vol. 1.* Amsterdam: North Holland.

Bellugi, U., Tzeng, O.J.L., Klima, E.S. & Fox, A. (1990). Dyslexia: Perspectives from sign and script. In A. Galaburda (ed.), *From neuron to reading: Toward a neurobiology of dyslexia* (pp. 137-171). Cambridge: Bradford Books/MIT Press.

Brady S.A., and Shankweiler, D.P. (eds.). (1991). *Phonological processes in literacy: A tribute to Isabelle Y. Liberman.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Chang, J.M., Hung, D.L. & Tzeng, O.J.L. (1992). Miscue analysis of Chinese children's reading behavior at the entry level. *Journal of Chinese Linguistics,* 20(1):120-159.

Chang, J.M., Lee, W.L., Loo, S. & Tzeng, O.J.L. (1990). A multiple-cue analysis on reading Chinese: Comparisons between elementary readers in Taipei and Singapore. Paper presented at The Third International Symposium on Teaching Chinese as Foreign Language, sponsored by Chinese Language Society, Beijing, China, August 15-20.

Chang, J.M., Rueda, R.S., Tzeng, O.J.L. & Bos, C.S. (1992). Locus of reading disabilities: Clues from a Chinese study. Unpublished manuscript. College of Education, San José State University.

Coltheart, M. (1980). Deep dyslexia: A review of the syndrome. In M. Coltheart, K. Patterson & J.C. Marshall (eds.), *Deep dyslexia.* London: Routledge & Kegan Paul.

DeFrancis, J. (1989). *Visible speech.* Hawaii: University of Hawaii Press.

Dejerine, J. (1891). Sur un cas de cecite verbale avec agraphie suivi d'autopsie. Mémoires Societé Biologique, 3:197-201.

Erickson, D., Mattingly, I.G. & Turvey, M.T. (1977). Phonetic activity and reading: An experiment with Kanji. *Language and Speech*, 20:384-403.

Fang, S.P., Horng, R.Y. & Tzeng, O.J.L. (1986). Consistency effects in the Chinese character and pseudo-character naming tasks. In H. Kao & R. Hoosain (eds.), *Linguistics, Psychology, and the Chinese language*. Hong Kong: University of Hong Kong Press.

Gleitman, L.R. & Rozin, P. (1977). The structure and acquisition of reading: Relation between orthographic and the structure of language. In A.S. Reber & D.L. Scarborough (eds.), *Toward a psychology of reading: The proceeding of the CUNY conference*. Hillsdale: Lawrence Erlbaum Associates.

Glushko, R. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance*, 5:674-691.

Gough, P.B. (1972). One second of reading. In J.P. Kavanagh & I.G. Mattingly (eds.), *Language by ear and by eye*. Cambridge, MA: MIT Press.

Gough, P.B. & Cosky, M.J. (1977). One second of reading again. In N.J. Castellan, D.B. Pisoni & G.R. Potts (eds.), *Cognitive theory, Vol. 2*, Hillsdale, NJ: Lawrence Erlbaum Associates.

Hardyck, C., Tzeng, O.J.L. & Wang, W.S-Y. (1977). Cerebral lateralization effects in visual half-field experiments. *Nature*, 269:705-707.

Hardyck, C., Tzeng, O.J.L. & Wang, W.S-Y. (1978). Cerebral lateralization of function and bilingual decision processes: Is thinking lateralized? Brain and *Language*, 5:56-71.

Hasuike, R., Tzeng, O.J.L. & Hung, D.L. (1986). Script effects and cerebral lateralization. In J. Vaid (ed.), *Language processing in bilinguals: Psycholinguistic and neuropsychological perspectives*. pp. 275-288, N.J.: Lawrence Erlbaum Associates.

Hatano, G., Kuhara, K. & Akiyama, M. (1981). Kanji helps readers of Japanese infer the meaning of unfamiliar words. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition*, 3:30-33.

Hatta, T. (1977). Recognition of Japanese Kanji in the left and right visual field. *Neuropsychologia*, 15:685-688.

Hatta, T. (1981). Differential processing of kanji and kana stimuli in Japanese people: Some implications from Stroop-test results. *Neuropsychologia*, 19:87-93.

Hatta, T., Katoh, H. & Aitani, N. (1982). Does single kanji process dominantly in the right hemisphere? some implications from Stroop-test results. *International Journal of Neuroscience*, 18:67-72.

Hecaen, H. & Kremin, H. (1976). Neurolinguistic research on reading disorders resulting from left hemisphere lesions: Aphasia and "pure" alexia. In H. Whitaker & H.A. Whitaker (eds.), *Studies in Neurolinguistics, Vol. 2*. New York: Academic Press.

Henderson, L. (1982). *Orthography and word recognition in reading*. New York: Academic Press.

Hildebrandt, N. (1981). The Stroop effect with Japanese-English bilinguals. *Kinjo University Annuals, English Department*, 22.

Hinschelwood, J. (1917). *Congenital word-blindness*. London: Lewis.

Hirata, K. & Osaka, R. (1967). Tachistoscopic recognition of Japanese letter materials in left and right visual fields. *Psychologia*, 10:17-18.

Huang, C.Y. (1983). Varieties of deep dyslexia in Chinese orthography. Paper presented in the 6th Asian and Oceanian Congress of Neurology. Taipei, Taiwan, November 13-17.

Hung, D.L. & Tzeng, O.J.L. (1981). Orthographic variations and visual information processing. *Psychological Bulletin*, 90:377-414.

Hung, D.L., Tzeng, O.J.L., Lee, W.L. & Chang, J.M. (1994). Orthography, reading disability, and cerebral organization. In W.C. Watt (ed.), *Writing systems and cognition*. (pp. 11- 35). Amsterdam: Kluwer Academic Publishers.

Hung, D.L., Tzeng, O.J.L., Salzman, B. & Dreher, J. (1984). A critical evaluation of the horse-racing model of skilled reading. In H.S.R. Kao & R. Hoosain (eds.), *Psychological Studies of the Chinese Language*. Hong Kong: Chinese Language Society of Hong Kong.

Kay, J. & Marcel, A. (1981). One process, not two, in reading aloud: Lexical analogies do the work of non-lexical rules. *Quarterly Journal of Experimental Psychology*, 33A:397-413.

Kershner, J.R. & Jeng, A.G. (1972). Dual functional hemispheric asymmetry in visual perception: Effects of ocular dominance and post exposural processes. *Neuropsychologia*, 10:437-445.

Kintsch, W. & Van Dijk, T.A. (1978). Toward a model of text comprehension and production. *Psychological Review,* 85:363-416.

Klima, E.S. & Bellugi, U. (1979). *The signs of language.* Cambridge, MA: Harvard University Press.

Kroeber, A.L. (1948). *Anthropology: Race, language, culture, psychology prehistory* (new ed., rev.). New York: Harcourt, Brace.

Lee, W.L., Chang, J.M., Wee, C., Tzeng, O.J.L. & Hung, D.L. (November, 1991). Phonemic awareness and learning to read a logographic script. Paper presented at the 42nd annual conference of the Orton Dyslexia Society. Portland, Oregon.

Lee, W.L., Tzeng, O.J.L., Wee, G. & Hung, O.J.L. (1992). Intra- and Inter-language Stroop effects across three different scripts. In R. Harris (ed.), *Bilingual processing and cognition* (pp.427-442). Amsterdam: Elsevier Science Publishers.

Lee, W.L., Wee. C., Tzeng, O.J.L., and Cheng, L.O. (1989). The role of visuospatial & phonologic[1] memory in learning to reading Chinese. *Proceedings of the International Seminar on Chinese Language and Its Teaching in The World.* Singapore: Chinese Language Society.

Lee, W.L., Wee, G.C. & Wong, E. (November, 1987). Cognitive correlates of reading in English and Chinese amongst bilingual Chinese children in Singapore. Paper presented at the 38th annual conference of The Orton Dyslexia Society. San Francisco, California.

Leong, C.K. (1991). From phonemic awareness to phonological processing to language access in children developing reading proficiency. In D.J. Sawyer and B.J. Fox (eds.), *Phonological awareness in reading: The evolution of current perspectives.* (pp. 217-254). New York: Springer-Verlag.

Lien, Y.W. (1985). The reading process of Chinese character: The activation of phonetic information in the phonogram. Unpublished Master thesis, National Taiwan University.

Liberman, I.Y., Mann, V.A., Shankweiler, D. & Werfelman, M. (1982). Children's memory for recurring linguistic and non-linguistic materials in relation to reading ability. *Cortex,* 18:367-375.

Luria, A.R. (1970). *Traumatic Aphasia.* The Hague: Mouton.

Makita, K. (1968). The rarity of reading disability in Japanese children. *American Journal of Orthopsychiatry,* 38:599-614.

McCusker, L.X., Hillinger, M.L. & Bias, R.G. (1981). Phonological recoding and reading. *Psychological Bulletin*, 89:214-245.

Mann, V. (1986). Phonological awareness: The role of reading experience. *Cognition*, 24:65-92.

Mann, V.A. & Liberman, I.Y. (1984). Phonological awareness and verbal short-term memory: Can they presage early reading problems? *Journal of Learning Disabilities*, 17:592-599.

Marshall, J.C., Newcombe, F. (1973). Patterns of paraplexia: A psycholinguistic approach. *Journal of Psycholinguistic Research*, 2:175-199.

Mead, M. & Modley, R. (1968). Communication among all people, everywhere. *Natural History*, 77(7):55-63.

Miller, R.A. (1980). *Origins of the Japanese Language*. Seattle: University of Washington Press.

Morais, J., Cary, J., Alegria, J. & Bertelson, P. (1979). Does awareness of speech as a consequence of phonemes arise spontaneously? *Cognition*, 7:323-331.

Park, S. & Arbuckle, T.Y. (1977). Ideograms versus alphabets: Effect of script on memory in "biscriptural" Korean subjects. *Journal of Experimental Psychology: Human Learning and Memory*, 3:631-642.

Read, C., Zhang, Y.F., Nie, H.Y. & Ding, B.Q. (1986). The ability to manipulate speech sounds depends on knowing alphabetic writing. *Cognition*, 24:31-44.

Rozin, P., Poristsky, S. & Sotsky, R. (1971). American children with reading problems can easily learn to read English represented by Chinese characters. Science, 171, 1264-1267.

Rubenstein, H., Lewis, S.S. & Rubenstein, M.A. (1971). Evidence for phonemic recoding in visual word recognition. *Journal of Verbal Learning and Verbal Behavior*, 10:645-657.

Saffran, E.M. & Marin, O.S.M. (1977). Reading without phonology: Evidence from aphasia. *Quarterly Journal of Experimental Psychology*, 29:515-525.

Sasanuma, S. (1974). Impairment of written language in Japanese Aphasics: Kana vs Kanji processing. *Journal of Chinese linguistics*, 2:141-57.

Sasanuma, S. (1975). Kana and kanji processing in Japanese aphasics. *Brain and Language*, 2:369-383.

Sasanuma, S. (1980). Acquired dyslexia in Japanese: clinical features and underlying mechanisms. In M. Coltheart, K. Patterson & J.C. Marshall (eds.), *Deep Dyslexia*. London: Routledge & Kegan Paul.

Sasanuma, S. & Fujimura, O. (1971). Selective impairment of phonetic and nonphonetic transcription of words in Japanese aphasic patients: Kana vs. Kanji in visual recognition and writing. *Cortex*, 7:1-18.

Sasanuma, S., Itoh, M., Mori, K. & Kobayashi, Y. (1977). Tachistoscopic recognition of Kana and Kanji words. *Neuropsychologia*, 15:547-553.

Seidenberg, M.S. (1985). The time course of phonological code activation in two writing systems. *Cognition*, 19:1-30.

Sergent, J. (1983). Role of the input in visual hemispheric asymmetries. *Psychological Bulletin*, 93:481-512.

Shankweiler, D. & Crain, S. (1986). Language mechanisms and reading disorders: A modular approach. *Cognition*, 24:139-168.

Singer, H. & Ruddell, R.B. (eds.) (1985). *Theoretical models and processes of reading* (3rd. ed.). Newark, DE: International Reading Association.

Smith, M.C. & Krisner, K. (1982). Language and orthography as irrelevant features in color-word and picture-word Stroop interference. *Quarterly Journal of Experimental Psychology*, 34A:153-170.

Stanovich, K.E. (1985). Cognitive processes and the reading problems of learning disabled children: Evaluating the assumption of specificity. In J.K. Torgesen B. Wong (eds.), *Psychological and educational perspectives on learning disabilities* (pp. 87-132). New York: Academic Press.

Stevenson, H.W. (1984). Orthography and reading disabilities. *Journal of learning disabilities*, 17(5):296-301.

Stevenson, H.W., Stigler, J.W., Lucker, G.W., Lee. S.Y., Hsu, C.C. & Kitamura, S. (1982). Reading disabilities: The case of Chinese, Japanese, and English. *Child Development*, 53:1164-1181.

Stroop, J.R. (1935). Studies of interference in serial verbal reaction. *Journal of Experimental Psychology*, 18:643-662.

Tatsumi, I.F., Itoh, M., Konno, K., Sasanuma, S. & Fujisaku, H. (1982). Identification of speech, kana and kanji, and the span of short-term memory for auditorially and visually presented stimuli in aphasic patients. *Annual Bulletin of R.I.L.P.*, 16:205-218.

Torgesen, J.K. (1988). Studies of children with learning disabilities who perform poorly on memory span tasks. *Journal of Learning Disabilities*, 21(3):605-612.

Torgesen, J.K. (1989). Cognitive and behavioral characteristics of children with learning disabilities: Concluding comments. *Journal of Learning Disabilities*, 22(3):166-168.

Turvey, M.T. (1984). Investigations in a phonologically shallow orthography. Paper presented at the Third International Symposium on Psychological Aspects of the Chinese Language. Hong Kong.

Tzeng, O.J L. (1981). Relevancy of experimental psychology to reading instruction. In O.J.L. Tzeng and H. Singer (eds.), *Perception of print: Reading research in experimental psychology*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tzeng, O.J.L., Hung, D.L. (1981). Linguistic Determinism: A Written Language Perspective. In O.J.L. Tzeng & H. Singer (eds.), *Perception of print: Reading Research in Experimental psychology*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tzeng, O.J.L. & Hung, D.L. (1988). Cerebral organization: Clues from scriptal effects on lateralization. In I-M. Liu, H-C. Chen & M.J. Chen (eds.), *Cognitive aspects of the Chinese language, Vol. I.* (pp. 119-139). Hong Kong: Asian Research Service.

Tzeng, O.J.L. & Hung, D.L. (in press). Location-specific inhibition in visual selection attention. *Psychological Science*.

Tzeng, O.J.L., Hung, D.L. & Lee, W.L. (1991, March). A conspiracy effect in the recognition of Chinese characters. Paper presented at the Conference on From Spoken to Written Languages, Bellagio, Italy.

Tzeng, O.J.L., Hung, D.L., Cotton, B. & Wang, W.S-Y. (1979). Visual lateralization effect in reading Chinese characters. *Nature*, 282:499-501.

Tzeng, O.J.L., Hung, D.L. & Wang, W.S-Y. (1977). Speech recording in reading Chinese characters. *Journal of Experimental Psychology: Human Learning and Memory*, 3:621-630.

Tzeng, O.J.L. & Singer, H. (1978-79). Failure of Steinberg and Yamada to demonstrate superiority of Kanji over Kana for initial reading instructions in Japan. *Reading Research Quarterly*, 4:661-667.

Tzeng, O.J.L. & Singer, H. (1981). *Perception of print: Reading research in experimental psychology*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Tzeng, O.J.L. & Wang, W.S-Y. (1983). The first two R's. *American Scientist*, 71:238-243.

Venezky, R.L. (1970). Regularity in reading and spelling. In H. Levin & J.P. Williams (eds.), *Basic studies on reading*. New York: Basic Books.

Wagner, R.K., and Torgesen, J.K. (1987). The nature of phonological processing and its causal role in the acquisition of reading skills. *Psychological Bulletin*, 101(2):192-212.

Wang, W.S-Y. (1973). The Chinese language. *Scientific American*, 228(2):50-60.

Wang, W.S-Y. (1981). Language structure and optimal orthography. In O.J.L. Tzeng & H. Singer (eds.), *Perception of print: Reading research in experimental psychology*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Zaidel, E. & Peters, A.M. (1981). Phonological encoding and ideographic reading by disconnected right hemisphere: Two case studies. *Brain and Language*, 14:205-234.

Zhou, Y.G. (1978). To what degree are the "phonetics" of present-day Chinese characters still phonetic? *Zhongguo Yuwen*, 146:172-177.