Chinese Characters and Word Recognition: An Analysis and a Model

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ABSTRACT

Designations have been used very inconsistently in deciphering the nature of the Chinese writing system, ranging from pictographic, ideographic, logographic, to morphemic, phonosemantic, ideophonographic, and even to logosyllabic, word syllabic, morphosyllabic, etc. Implicit in the inconsistence is a set of hypotheses that Chinese is not a phonetic script, Chinese characters are represented in the right hemisphere and thus are processed in a picture-like fashion, and that recognizing Chinese characters does not involve phonological mediation, and so on. This thesis provides a thorough discussion of the linguistic structure underlying the organization of Chinese characters, and offers a perspective on the linguistic organization and the psycholinguistic processes involved in the recognition of Chinese characters. Misconceptions and fallacies concerning Chinese characters in both linguistic and cognitive areas are challenged and clarified. The thesis begins with a linguistic analysis of Chinese characters, focussing on the formal properties around which processing interpretations revolve. It then discusses issues of visual, hemispheric and cognitive processing of Chinese characters (e.g., how a Chinese character is visually detected? are Chinese characters represented in the right hemisphere? how are they processed in the two hemispheres? under what circumstances are Chinese characters visually accessed? and through what means if a Chinese character is to be phonologically coded? etc.). Lastly, an interactive model of Chinese character recognition is proposed. It is hoped that the groundwork may serve as the basis for proper experimental psycholinguistic research in future.

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CHAPTER 1

Introduction

The Chinese writing system is perhaps the only oldest writing system in the world that is still in use since its invention. In deciphering the nature of the Chinese writing system, designations have been used very inconsistently, ranging from pictographic ideographic, logographic, to morphemic, phonosemantic, ideophonographic, and even to logosyllabic, word syllabic, morphosyllabic, etc. (see Defrancis, 1984). Implicit in these perspectives is a set of hypotheses that Chinese is not a phonetic script, Chinese characters are represented in the right hemisphere and thus are processed in a picture-like fashion, and that recognizing Chinese characters does not involve phonological mediation, and so on.

The objective of the thesis is to provide a thorough discussion of the linguistic structure underlying the organization of Chinese characters, and to offer a perspective on the linguistic organization and the psycholinguistic processes involved in the recognition of Chinese characters. Misconceptions and fallacies concerning Chinese characters in both linguistic and cognitive areas will be challenged and clarified.

The thesis will begin with a linguistic analysis of Chinese characters, focussing on the formal properties (e.g., visual, phonological and semantic information encoded in the characters) around which processing interpretations revolve. It serves as a background to later discussion of how Chinese characters are processed. The rest of the thesis will be devoted to discussing issues of visual, hemispheric and cognitive processing of Chinese characters. Fundamental questions (e.g., how a Chinese character is visually detected? are Chinese characters represented in the right hemisphere? how are they processed in the two hemispheres? under what circumstances are Chinese characters visually accessed? and through what means if a Chinese character is to be phonologically coded? etc.) will be dealt with in some detail. An interactive model is also proposed on the basis of the discussion. According to this model, visual features are extracted while the character is fixated. Extraction of the features is carried out by the RIGHT track and the LEFT track, both operating in parallel. If the character is familiar, it is recognized by its shape and the outer contour; if the character is familiar but visually complex, it is decomposed into subunits. The operation in this route is direct and fast. If a character is less familiar, it is recognized phonologically; the operation in this route is slow.

In overview, the contribution of the thesis involves (a) a refined linguistic perspective; (b) a critical analysis of the relevant experimental literature on the processing of Chinese characters; (c) an interactive model of the processing system for Chinese characters, guided by (a) and (b). This groundwork may serve as the basis for proper experimental psycholinguistic research in future.

CHAPTER 2

Chinese Characters: A Linguistic Perspective

Designations given to describe the symbols that represent the Chinese script in the Western world have been varied and inconsistent. A most specialized term is "Chinese characters". It is usually clear enough to serve as an overall designation for the basic symbols. As the term contains two words, numerous attempts have been made to use one word in place of two. A recently coined synonym "Sinograph" (Rogers, 1977) is an example. But a more popular view of the nature of Chinese writing is reflected in the wide spread use of the designation "pictographs" . This term is meant to indicate that the basic units of writing are pictures divorced from sound and their meaning can be readily discernible, even when the symbols are conventionalized or stylized in form. Another widely used term is "ideographs", which has a specific meaning: it designates that written symbols represent ideas, abstract as well as concrete, without regard to sound. The same symbol can evoke the same idea in the minds of different viewers. Opposite to this designation that the symbols represent concepts is the term "logographs" or "lexigraphs" which emphasizes that written symbols in Chinese represent specific words. There are others, however, who argue that Chinese characters represent morphemes rather than words, they insist that the logographic concept should be modified as "morphemic" or "morphographic" (Robert and Cheng, 1980). Those who show concern about the phonetic elements in Chinese characters, nevertheless, suggest such terms as "phonograms", "phonetic compounds". Other concerns (see Defrancis, 1984) such as both the semantic and phonetic aspects should be taken into account in the naming of Chinese characters have led to terms like "phonosemantic", and "ideophonographic", "phonoideograms". Additional terms are "logo-syllabic", "word-syllabic", "morphosyllabograph", which relate Chinese characters both to words and syllables.

Of all these specific names proposed for Chinese characters, both "pictographs" and "ideographs" are very inappropriate, for they ignore the overwhelming majority of the characters that contain both a semantic element and a phonetic element. "Logographs" or "lexigraphs" are proper to some extent, but are less adequate in comparison with "phonosemantic" and "ideophonographic" which suggest the two key aspects in question. Together, they are not sufficiently precise. "Logo-syllabic" and "word-syllabic" seem to come closer to the requirement, but further refinement is still needed (see Defrancis, 1984). A term currently considered quite precise is Defrancis's "morphosyllabograph" or more specifically "morphosyllabic", because it succeeds in capturing some basic characteristics of Chinese characters.

Characteristics of Chinese Characters

In Chinese, every character represents a morpheme and is pronounced as a single syllable in general. A word, which is different from a character, in many cases, also contains a monosyllabic morpheme. This distinctive feature of monosyllabism, however, cannot be taken as that all the words in the language consist of single syllables; instead, a single syllable is an important phonological unit and often is a morphemic unit.

Take the word 山 /shan/ "mountain" for example, it is one morpheme, one syllable and one character. This characteristic differs greatly from its English counterpart *mountain* which is decomposable into two morphemes and two syllables. Disyllabic or polysyllabic words only account for a minority in Chinese. Of them, there is a handful of disyllabic words which form single morphemes, neither half of which have any meaning or function without the other. The word 蝴蝶, for example, contains 2 characters and 2 syllables. However, if we look up a dictionary, one entry presents the character 蝴 with the pronunciation /hu/ and the definition "the butterfly". Another entry presents the character 蝶 with the pronunciation /die/ and the definition "the butterfly". The first entry also presents both characters as the combination 蝴蝶 with the pronunciation /hudie/ and the definition "the butterfly". The second entry also presents both characters as the combination with the pronunciation /hudie/ and the definition "the butterfly". Which character is exactly "the butterfly", nobody knows. A possible explanation is that both /hu/ and /die/ and the disyllable /hudie/ do not exist in current spoken and/or colloqual Chinese, both syllables are reading pronunciations (Defrancis, p. 180).

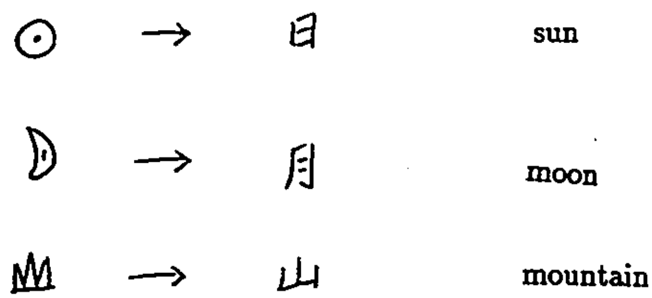
Another feature is that while one character represents one morpheme, a morpheme is always invariant. Thus one character may serve as "I", "me", "my" and another as "go goes, went, gone" and "going", occasionally aided by bound morphemes. This treatment of characters as if they were isolated units makes it opaque in knowing whether a particular character represents a noun, an adjective, a verb or other parts of speech. For example, the character for the adjective "large" 大 might be used as "largeness", "largely" or "enlarge". Word meanings are determined by word order. This lack of inflections to indicate grammatical categories has had Chinese been classified as "primitive". In fact, this uniformity in Chinese had not always existed. Karlgren (1962) observed that as early as the Zhou dynasty (1027-256 B.C.), there were case-inflections in personal pronouns and phonological variations in verb expressions:

> The prose of Zhou dynasty has been shown to possess case inflection in personal pronouns. Just as English has nowadays no inflectional distinction in nouns between nominative "the man" and accusative "the man", but still preserves a trace of an older stage in the pronouns I, me, thou, thee; in the same way Chinese had formerly nominative ngo "I", accusative nga "me", nominative ńi̭o "thou", accusative ńi̭a "thee"...... Word stems could be phonetically varied to express different grammatical functions. For example, d'âk "to measure" (verb), d'âg "a measure" (noun), just as in English sing (verb), song (noun) — A common mode of derivation in various languages (p. 15).

If this is correct, the argument that Chinese is a primitive language, not yet raised to the inflectional and derivative stage is erroneous. Chinese might have followed exactly the same line of evolution as the Indo-European languages in the gradual loss of syntactic termination and phonetic stem variations (Karlgren, 1962). To put it in another way, inflection is a by product of language development lagging behind the development of concept (Xu and Yuan, 1989).

The use of both semantic and phonetic elements to form a character is another distinctive feature which is universally recognized. Chinese characters, based on their origin, are conventionally grouped into six categories:

1. Pictographs, the oldest category, are characters based on pictures of objects. The most common examples are the iconic representations of concrete objects such as moon, sun, and mountain:



2. Ideographs express relational or abstract concepts that cannot be basically depicted by pictures: 一 "one", 二 "two", 丄 → 上 "up", 丅 → 下 "down".

3. Compound ideographs are those formed on the basis of associations of ideas suggested by their constituent parts which usually are pictographs or ideographs. For example, 明 "bright" is formed by combining two pictographs 日 "sun" and 月 "moon"; 東 is formed by placing 日 behind the pictograph 木 , and 坐 "to sit" means two 人 "man" on the 土 "ground".

4. Analogous characters are mainly new characters patterned after old ones so that they are analogous in meaning but do not share the same sound. For example, 老 /lao/ "old", if the final upward stroke is turned downward, becomes 考 /kao/ "to examine" (youngsters are generally examined by their elders).

5. Loan characters are those adopted for new characters on the basis of identity of sound. "come" is derived from 來 (a pictograph for "wheat") for its phonetic value, which would otherwise be difficult to depict.

6. Semantic and phonetic compounds form by far the largest category comprising at least 80-90% of the characters. Each character in this category consists of two elements: a signific, commonly called a radical, and a phonetic, The former determines the meaning and

the latter suggests the pronunciation. Thus, 河 "river" with radical 氵 signifying "water", and 可 /he/ as the phonetic, gives the logograph that is both intelligible and pronounceable.

This last category is unique but controversial. Radicals generally provide cues to character meanings, but the clues to meaning are not always accurate. The same is true of phonetics, they generally cue to but do not ascertain sounds of characters. Interestingly, the same component can be used either as a radical or a phonetic in different characters, thus creating more confusions. Complaints like "each character has a distinctive form, but on seeing the form, one cannot read the sound, and upon reading the form and reading the sound, one still does not necessarily understand the meaning of the character ..." may often be heard.

These pecularites together with the controversies contribute to the difficulty in describing Chinese characters. The reason we say that "morphosyllabic" is more precise is because it suggests that each character is pronounced as a single syllable and represents a single morpheme. Moreover, for the overwhelming majority of semantic + phonetic characters, "morphosyllabic" suggests that the radical represents a morpheme that may provide a clue to the meaning of the whole character, whereas the phonetic represents a syllable that may indicate the pronunciation of the character. Moreover, it is more informative than "logographic", "lexigraphic", "morphemic" or "morphographic" since these terms merely say that Chinese characters represent words or morphemes without telling how they do so. By contrast, "morphosyllabic" suggests that they do so via the intermediary of some elements representing a syllable (Defrancis, 1984). These characteristics and controversies will get clear as we proceed in the following, especially when Chinese characters are discussed in relation to reading.

Chinese Characters as Symbols

Chinese characters are pictographic in origin, but they are not picture-like in the sense of iconicity. They are linguistic symbols, each of which represents one morpheme which is one spoken syllable. One of the most important achievements in the history of evolution is the invention of symbols to represent the spoken language rather than using picture-drawings to express a general idea (Tzeng and Hung, 1981). This invention marks a stage that Chinese writing started to evolve away from primitiveness.

From Picture-drawings to Symbols

In primitive times, people wrote on rocks, tortoise, or shells to achieve some form of communication. These drawings were usually pictures of objects that immediately evoked meaningful interpretations. Nevertheless, picture drawings suffer obvious difficulties. For example, not everyone is able to draw pictures well to express; abstract concepts are difficult to express by pictures; different ways of arranging objects within a picture result in different interpretations. An unambiguous picture could sometimes be disadvantageous in that it can be easily interpreted by persons for whom it was not intended and hence can be misused (Tzeng and Hung, 1981). Because of these difficulties, new systems had to be invented.

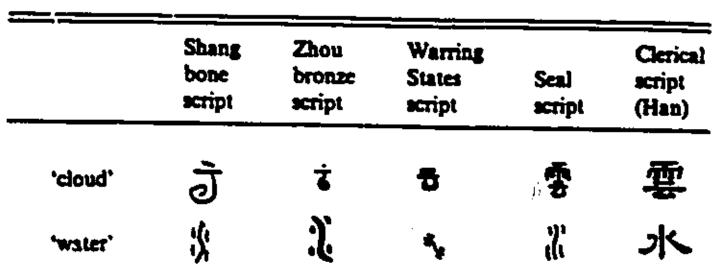
An insightful step taken is that instead of drawing pictures to express ideas, symbols were invented to directly represent speech. Thus, pictograms (e.g., 木 for tree), which were carried over from the picture-drawing stage were combined together to suggest ideas. For example, putting two trees side by side to mean "grove" 林 , and stacking three trees together to mean "forest 森 ; repeating 女 "woman" twice 奻 to mean "quarrel" (two women cannot be on good terms), and repeating it thrice 姦 to mean "intrigues among and with woman"; a woman sitting under a roof 安 symbolizes "peace". By this principle of metonymy, many ideograms were invented to represent ideas and feelings of various kinds. With this new invention, the language, as Glahn (1973) observes, "is already half way to poetry".

However, there were still difficulties in forming characters to represent abstract concepts. This need led to the invention of phonograms which were typically made of two or more components, one of which was not used for its semantic content, but for its phonetic value.

With the combination of these three methods, virtually an infinite number of characters may be created to represent all words used in the spoken language. The number of character thus increased from approximately 1,000 deciphered characters in the shang oracle bones (700 B.C.) to almost 10,000 in the Han (206 B.C.-220 A.D.), despite the Qin reform (221 B.C.) that eliminated so many characters. The number soared to 23,000 in the 12th century A.D. and almost 49,000 in the 18th century.

Form Changes

From the oracle bones to the present, the history of Chinese characters stretches back more than several thousand years. Archaeological findings suggest that Chinese characters had reached a fairly advanced stage of development by around 1400 B.C., capable of recording the contemporary Chinese language in a complete and unambiguous manner (Norman, 1988; Taylor and Taylor, 1983). On this fairly long course of evolution, the visual aspect of the Chinese characters had undergone drastic changes. It is observed that characters inscribed on oracle bones and on bronze vessels had progressively begun to lose some of the pictographic quality, due to the growing importance and the prevalent use of writing in society. A general phenomenon observed in the oracle bone inscription and the bronze inscription is the tendency to simplify and rationalize the linear structure of the symbols by straightening out the strokes and converting earlier rounded strokes to sharp angles. With the establishment of the first empire of Qin, which is considered to be a great watershed in the history of Chinese writing, came a rapid reform in character writing: not only were the characters standardized, they were simplified towards less pictographic forms. The "seal script" of Qin which was known from its widespread use of seal and which was ancestral to all later forms of Chinese writing had changed to such a degree that its ultimate pictographic origins became totally obscured. With the end of the Qin dynasty and the establishment of the Han dynasty, the seal script gradually gave away to "clerical script", which was mainly a creation of the clerks and low-level officials of the government chanceries. It is a new, modified script characterized by a rather more undulant and regular style of brushwork. This transition from the seal script to the clerical script and the subsequent universal adoption of the clerical script in the Han dynasty marks the change from the ancient form of writing in which the essentially pictographic roots of the script could still be discerned to a more purely conventionalized form of writing. In this change, all attempts to preserve the pictorial nature of symbols were abandoned and convenience became the overriding principle. Rounded and circular strokes are straightened out and linearized to make character easier to write: the character for sun  , for example, in the seal script was a circle with a short horizontal line through it, now it becomes a small square crossed by a short horizontal stroke, thereby loosing its earlier pictorial aspect. Character components are simplified and consolidated; a number of components distinctive in the seal script are merged, and commonly recurring components are given variant shapes depending on what position they occupy in the whole character. The change of form from the oracle bone inscription to the bronze inscription and from the seal script to the clerical script can be seen in the following examples:



(from Norman, 1988)

The "standard script" in use today is based on the clerical scripts in its classical Han form. It represents a further evolution toward a more regular and convenient form of writing in which the smooth, wavelike strokes of the clerical script are transformed into straighter lines and sharper angles. For a contemporary person, who has a good knowledge of the standard script, the clerical script can for the most part be read, whereas it takes specialized training and a great deal of practice to read a text written in the seal script. Examples (cf.

Norman, 1988) of the various types of scripts are shown in Table 1 in the following:

seal	clerical	standard	Zhāngcǎo	Cǎoshū
秋	秋	秋	秋	秋
收	收	收	收	收
冬	冬	冬	冬	冬
藏	藏	藏	藏	藏
閏	閏	閏	閏	閏
餘	餘	餘	餘	餘
成	成	成	成	成
歲	歲	歲	歲	歲
律	律	律	律	律
呂	呂	呂	呂	呂

Table 1

While form stylization of Chinese characters had undergone a large scale revision, character simplification which was initiated almost simultaneously with the form stylization had little change. The invention of symbols simplified stroke formation and reduced the number of strokes in ideographs and phonograms, the majority of characters which were visually complex and dense remained unchanged in the two millennia or more from Qin to Qing (1644-1911). Any attempt toward simplification was never strong enough to encounter conservative attitude which was opposed to virtually any innovation. It was not until the early 20th century when simplification gained a widespread acceptance. But again, owing to conservative oppposition, advocates of character simplification were heard, but not heeded, and most of the work just stayed at the committee stage. After 1949, the government of the People's Republic of China took a stand in favor of simplification of characters as a means of achieving universal literacy. The State Council ratified lists of 515 drastically simplified characters in 1956. A further list of more than 2,000 simplified characters was put into effect in 1964. Many frequently used characters have been simplified by abolishing hundreds of variants (characters with the same sound and meaning, but different forms), and by reducing the number of strokes in complex characters. The average number of strokes was 16 for a few thousand common characters in the original form, but only 10.3 for the 2238 simplified characters (Cheng, 1977), and characters that have fewer than 11 strokes comprise 56.6% of the 2500 most common characters. Though this process of character simplification was not as drastic as the switch from the seal script to the clerical script in the Han dynasty, it does represent a thoroughgoing reformation of the way in which Chinese is written. Table 2 below gives 10 simplified characters currently in official use, along with their former non-simplified forms.

Structure of simplified characters

1. 云(雲)	yún 'cloud'	6. 洁(潔)	jié 'clean'
2. 礼(禮)	lǐ 'ritual'	7. 里(裏)	lǐ 'inside'
3. 后(後)	hòu 'behind'	8. 扑(撲)	pū 'pounce'
4. 医(醫)	yī 'doctor'	9. 历(歷)	lì 'undergo'
5. 门(門)	mén 'door'	10. 让(讓)	ràng 'allow'

Table 2

There is one thing which seems very well preserved despite all the changes in form throughout the history: aesthetics. Aesthetics plays an exceedingly important role in Chinese writing, more so than in any other system of writing. As Martin (1972) notes, the shape of the Chinese characters reflects a two thousand-year history of brushwork calligraphy, in which one of the most important features is equidimensionality (p. 81) Every Chinese character built up in its own shape presents to the reader a formal design the abstract beauty of which is capable of drawing the mind away form the literal meaning of the characters (Yee, 1973, p. 107). All the strokes of a character are grouped in such a way that "they not only balance perfectly with each other but together form a unit which is complete in itself and which would be upset if any stroke were to be taken away" (Yee, 1973, p. 119). The following illustrations demonstrate how much of art and how little of mechanical design there is in Chinese characters:

Fig. 1

Fig. 2

Fig. 3

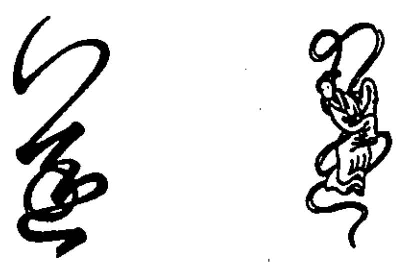


Fig. 4

Notes: Compare the character /xin/ in Fig. 1, which means 'heart', with the accompanying picture, the three dots are seen to occupy corresponding postions to the man, the oar, and the awning, while the elongated curve has the semblance of the boat. The whole character seems to be proceeding serenely down a river. In Fig. 2, the character /zu/ means 'foot', and, appropriately, it compares with a dignified bishop stepping ceremoniously down, perhaaps, the aisle of Westminster Abbey! Fig. 3 comprises the character /yi/

for 'thought' and the figure of a person seated at ease. There is no suggestion of a wooden image in the character, but the imaginary person, from the inward movement of the strokes, seems to have a pensive demeanour. Fig 4 shows the character /sui/, 'to follow' The movement of the strokes suggests speed, but a dancing rather than a racing speed The formation of the character is amazingly good, every stroke joined to the next in a continous mobile line, like the contours of a dancing girl with her floating draperis

(from Yee, 1973)

It is, of course, impossible to find pictures to correspond as closely as these with every character, but the principle holds for all: the character must have the balance of a human being or natural or other object caught in the act of moving.

Stylization and simplification have had the result, in many cases, that the original image is lost, but for some characters there is still a vivid enough image to evoke the reader's feeling and stir associations with the characters. Take the character 笑 "smile", for example, it is constructed from the two characters ⺮ "bamboo" and 夭 "die young". Obviously, there is no fundamental relationship between bamboo and smile in meaning . It must have been formed on the basis of the principle of aesthetics. In fact, people who know the character when they see it can feel that they are seeing a smile because the form of the character does resemble a person smiling. Similarly, when people see the character 哭 "cry", they really feel that a person is crying. Of course, aesthetics encoded in the characters can only be decoded by those people who are familiar with the characters, because this process of decoding, namely, the imagination of the shape of the object through a character, is a cultivated mental activity which may be attributed to cultural acculturation.

Structure of Chinese Characters

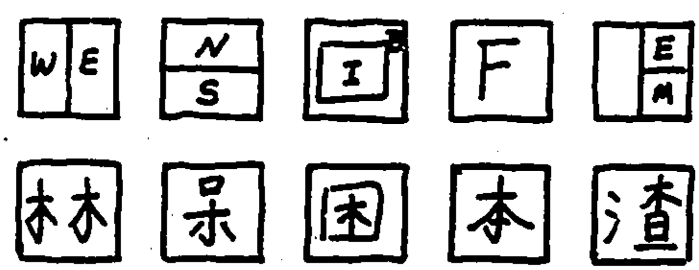
Chinese characters are, in general, composed of components, and each component can be written with a fixed cluster of strokes. A stroke is a mark made with a single continuous motion of the pen; it is a building block for the shape of a character and it does not have individual semantic and phonetic functions. There are three general categories of strokes: dots, lines and hooks. These can be illustrated as follows:

dots: ㇒ ㇏

lines: 一 丨 ㇀

hooks: 

The strokes in Chinese characters apparently are arbitrary and vary a great deal, the number of strokes as a matter of fact is very small—around 15 to 20, corresponding roughly to the alphabetic letters (Wang, 1971). In addition, they are often used in a fixed order, forming clusters similar to certain clusters of letters always going together at the beginning rather than at the end of a word in English. Some of the clusters serve as radicals, while some may serve as phonetic components for a word. Some clusters may be used more frequently than others (Leong, 1973). The average number of strokes in a Chinese character is about 6-8, though many may contain just as few as one or two or as many as 20 strokes. For those characters that contain many strokes, and thus are complex, they have an internal structure analyzable into two or more components: these components are assigned or arranged in a way that they occur in a specific position. As the position of some components varies from character to character, they form different configurations within the square. In principle, the component combination of Chinese character falls into the following categories: West (W), East (E), North (N), South (S), Border (B), Interior (I), Free (F) (Leong, 1973), and Embedded (EM) etc. (Rankin et al., 1966) as shown below:



The first two categories (i.e., W/E. N/S) account for almost 90% of the characters in current use (Chen, 1982, cited in Defrancis, 1984, p. 77). The internal structure of every character, no matter how many strokes it has, is compactly built, forming an overall shape. They either take up the full square as in 日 "sun" 凸 "convex" or balance vertically as in 门 "door" or 休 "rest", or horizontally as in 早 "early", or balance in a tripartite vertical form as in 淋 "to sprinkle" or three ways as in 森 "forest" (Leong, 1973). The internal constituency that Chinese characters are constructed is somewhat like a pattern

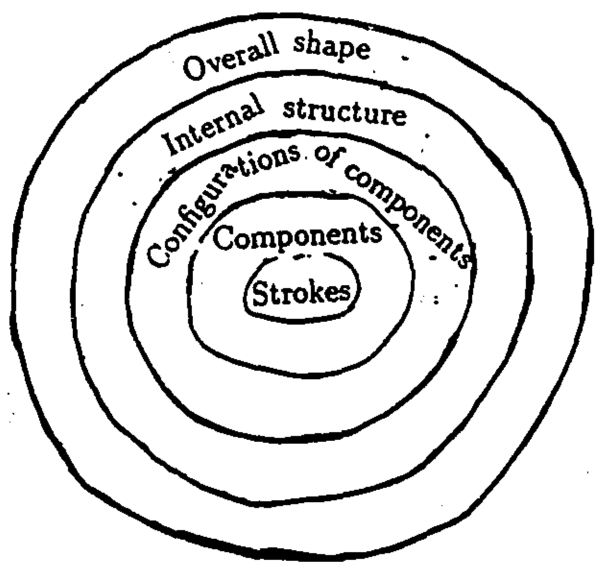


Figure 1

Perceived this way, Chinese characters as a whole add much more meaning to visual processing: they are not purely arbitrary graphic symbols bearing no clear-cut relationship to one another, but are rather made up of a relative small number of components together they contributing to a configuration. In his definition of individual characters in *shuowen jiezhi*,

China's first dictionary, Xu Shen (120 A.D.) took into account the fact that every character had a shape, a sound and a meaning. I have discussed in some detail the first one, and now I will turn to the other two respectively in the following:

Chinese Characters as Sounds

There are basically two ways for phonetic representation. A writing system can represent their phonemes, the smallest basic sounds of a language, as in the case of alphabetic scripts, or clusters of sounds comprising syllables, as in the case of the two Japanese kana syllabaries. Some systems appear to fall in between these two categories. Chinese characters, for example, are not based on any inventory of symbols comparable to alphabetic systems which possess an inventory of symbols to represent the individual phonemes. It is not alphabetic basically, but it is phonetic, or more specifically syllabic, for, Chinese has a syllabary which is somewhat different from the syllabic script used for Japanese.

The Phonetic Component in Characters

According to Western scholars who attempt to impose a phonological classification of Chinese characters, Chinese has a syllabary of about 850 or more phonetic elements. These phonetics occur wholly or in part in 90% of the characters (Defrancis, 1984). They provide phonetic clues to sounds, but do not ascertain an exact pronunciation. The reason for this closer fit but not a match is that Chinese did not follow the way that Japanese did in simplifying their syllabic signs to only a few strokes; nor did it adopt the procedure of limiting their syllabary to a fixed number of signs to be used in representing the totality of the language. To understand this problem, we may think of each character in the phonetic compound category in terms of two symbols and two sounds: one symbol is the phonetic element, the other is the the pronunciation of the whole character (Defrancis, 1984). Each of these two sounds is invariably a syllable. Sometimes, the syllable that constitutes the pronunciation of the phonetic element corresponds 100%, even to tone, to the syllable that represents the pronunciation of the whole character. Sometimes, the pronunciation of the phonetic element correctly indicates the pronunciation of the whole character except for tone. Sometimes only part of the pronunciation of the phonetic element corresponds to some part of the pronunciation of the whole character such as the initial or the final. Sometimes the pronunciation of the phonetic element has no point of correspondence with the actual pronunciation of the whole character. The syllabic nature of the phonetic elements can be seen in Table 3 in which the five degrees of possible/impossible correspondence between phonetic elements and full characters are illustrated by characters formed with phonetic 皇, 馬, 堯, 工, 多:

Complete identity

- 皇 *huáng*
- 惶 *huáng* "afraid"
- 煌 *huáng* "brilliant"
- 蝗 *huáng* "locust"
- 隍 *huáng* "moat"
- 鰉 *huáng* "sturgeon"
- 遑 *huáng* "hasten"
- 凰 *huáng* "female phoenix"

Identity except for tone in some cases

- 馬 *mǎ*
- 瑪 *mǎ* "agate"
- 碼 *mǎ* "weights"
- 螞 *mǎ* "ant"
- 鎷 *mǎ* "masurium"
- 媽 *mā* "mother"
- 榪 *mà* "clamp"
- 禡 *mà* "sacrifice"
- 罵 *mà* "scold"
- 嗎 *ma* "question particle"

Partial similarity in segmental phonemes

- 堯 *yáo* (*y* changes to *i* after a consonant)
- 僥 *jiǎo* "lucky"
- 澆 *jiāo* "sprinkle"
- 磽 *qiāo* "stony soil"
- 翹 *qiáo* "tail feather"
- 曉 *xiǎo* "dawn"
- 驍 *xiāo* "fine horse"
- 撓 *náo* "scratch"
- 橈 *náo* "oar"
- 譊 *náo* "dispute"
- 鐃 *náo* "hand bells"
- 嬈 *ráo* "graceful"
- 繞 *rào* "wind around"
- 蕘 *ráo* "rushes"
- 蟯 *ráo* "tapeworm"
- 饒 *ráo* "abundant"
- 燒 *shāo* "burn"

Similarity only in the initial and the final

- 工 *gōng*
- 訌 *hóng* "fight"
- 紅 *hóng* "red"
- 缸 *gāng* "jar"
- 杠 *gàng* "bar"
- 扛 *káng* "carry"
- 江 *jiāng* "river"

No identity

- 多 *duō*
- 侈 *chǐ* "wasteful"
- 移 *yí* "move"

Phonetic elements appear to be important in Chinese characters from Table 3. To what extent are they effective in suggesting the pronunciation of the characters of which they form part, since phonetics are pictographic in origin, and they occur not only independently but also quite frequently by themselves. Defrancis (1984) examines a cross section of 500 characters out of the 4,719 different characters that Chen (1928) found to occur in a frequency count of 900,000 characters of running text, he found that in the total sample of 500 characters, 18% are independent phonetics, and 79% are phonetic compounds, leaving only 3% with no phonetic aspect at all. High frequency characters include fewer phonetic compounds, while low frequency characters include more phonetic compounds. Highest frequency characters, such as the first hundred, are strikingly represented by phonetics functioning as independent characters. Decreasing rank order of frequency is marked by a decreasing number of independent phonetics, but by a greater number of phonetic compounds, especially compounds with useful phonetics. These two opposite trends, which cancel each other out, make a consistently high proportion (60-81%) of characters with a useful phonetic aspect.

Interesting also in the examination is that the hundred most frequently occurring characters alone comprise an astonishing 47% of the total of 900,000 characters of running text, and that the 1,100 most frequent occurring characters comprise approximately 90%. To interprete this finding in another way: if a reader of Chinese knows only a hundred characters, almost every other character in a piece of writing would be familiar to him. With a knowledge of 1,100 characters, only every tenth character would be unfamiliar, and in two-thirds of the remaining 90% of the characters that would be a useful phonetic clue to help the reader recall the pronunciation of the character... Thus a reader with a knowledge of the phonetic component in Chinese writing has two chances out of three of guessing correctly the pronunciation in reading (Defrancis, 1984, p. 128).

A similar study which was based on simplified characters was done by Zhou (1978). Of the 8,075 characters contained in the 1971 edition of Xinhua Zhidian, Zhou calculated that 1,348 (17%) are phonetic elements, 6,542 (81%) phonetic compounds, 185 (2%) nonphonetic characters. 3,117 (48%) of the 6,542 phonetic compounds contain useful phonetic elements, which he defines as phonetics identical except for tones. This figure, unfortunately, is often misquoted to argue against the claim that Chinese characters represent sounds (e.g., Just and Carpenter, 1987). In fact, as Defrancis notes, if we add this figure to the 17% comprised by the phonetics themselves, there will be a total of about 65% of the characters in the dictionary that are phonetically identifiable. If the criterion of usefulness is extended to include phontics with only partial correspondence in the segmental phonemes the overall figure would be even higher.

A conclusion that we can draw after this discussion is that the Chinese script may be considered to have a phonetic basis, belonging to "a single broad family of syllabic scripts" (Defrancis, 1984, p. 111), despite the poor correspondence between sound and symbol in Chinese. This classification seems reasonable if we keep the matter in historical aspect, as Gelb (1979, in Defrancis, 1984) observes:

> While the connections between language and writing are close, there has never been a one-to-one correspondence between the elements of language and the signs of writing. The "fit" (i.e., the correspondence) between language and writing is generally stronger in the earlier days and weaker in its later stages. This is because a writing system when first introduced generally reproduces rather faithfully the underlying phonemic structure (structure of sounds). In the course of time, writing, more conservative than language, generally fails to keep up with the continuous changes of language and, as time progresses, diverges more and more from its linguistic counterpart. A good example is the old Latin writing, with its relatively good "fit" between graphemes (the written letters or group of letters that represent one phoneme or individual sound) and phonemes as compared with present-day French or English writing, with their tremendous divergences between graphemes and phonemes. In some cases, recent spelling reforms have helped to remedy the existing discrepancies between writing and language. The best "fit" between phonemes and graphemes has been achieved in the Korean writing in the 16th century and in the Finnish and Czech writings of modern times. (p. 1041)

It is because of this defective inventory of syllabic symbols that the Chinese did not adopt a procedure of limiting their syllabary to a fixed number of signs to be used in representing the totality of the language. In other words, why was Chinese not phoneticized long ago? A brief discussion of this topic may provide some insight into this puzzle.

Why was Chinese not phoneticized long ago?

Proceeding from pictographic to ideographic to logographic and to phonetic seems to be the laws of the development of all writing systems (Li, 1958). The Egyptian writing system, for example, was developed in this way: it passed through the pictographic and ideographic, logographic stages and ultimately progressed to the phonetic stage. The Chinese writing system, however, did not go beyond the logographic stage although "phonetic elements had entered into the characters as early as Shang dynasty" (Norman, 1988), and phonetic compounds as they were made represented sounds fairly closely (Chao, 1976), and importantly, there had been signs showing that Chinese characters had been on the road toward becoming phoneticized symbols (e.g., increasing use of polysyllabic words instead of single characters to express a concept)(Guo, 1951). Theories purporting to account for this myth have varied. One commonly held view was that the Chinese writing style after choosing the semantic + phonetic method was consistently maintained, and that demand for progress was restrained by this method, thus it just stopped there. This is a good explanation, but it suffers from two weaknesses (Li, 1958): First, other writing systems (e.g., Egyptian) were not restrained by the semantic + phonetic method, why was Chinese alone restrained? Second, the evolution of the Chinese characters to the semantic + phonetic type was not a choice, or a chance, but a necessity.

The creation of ideographs, as we have discussed in the earlier section, reduced the difficulty in expressing an abstract idea, but it could not eliminate it altogether. These needs led to the creation of the semantic + phonetic method. For example, a pictograph was first borrowed for its phonetic value and then a semantic clue was added into it to eliminate the ambiguation as in the evolutionary development of 來 :

1. 來 (/lai/: "wheat")
2. 來 (/lai/: "come")
3. 徠 (/lai/: "come")
4. 萊 (/lai/: "thistle")

But pictographic writing could represent only the common characteristics of a class of things; it could not represent their specific characteristics. For example, the pictograph 鸟

/niao/ can portray only "bird" in general. To distinguish different methods, and the most convenient and most satisfactory way of doing so was that of adding phonetics. For example, 鸽, 鹅, 鸪 . With this new methcd of creating characters including phonetic elements, many characters which originally were not semantic + phonetic type were amalgamated with them, with the result that the semantic + phonetic method became dominated. This domination of semantic + phonetic method is a necessity in the development of every writing system, not a matter of chance or choice (Li, 1958). Since other writings were not restrained by the semantic + phonetic method, it seems unreasonable that Chinese characters alone are restrained, and they were stopped there after developing to the semantic + phonetic stage.

Another widely held view is that there were too many monosyllabic and homophonous words, and that there would have been no way of differentiating between them, if it had not been the semantic + phonetic characters. This reason is also less adequate: one positive fact is that regardless of how many homonyms there were in antiquity, communication among people did not seem hindered; another fact is that Vietnamese is a language dominated by monosyllabic words and has many homonyms, yet its writing system is phoneticized.

In fact, two major elements seem to be responsible for the arrest of Chinese writing essentially at the logographic stage: potentiality and dignity (Li, 1958). The goal of a writing system is to record and represent the language. By potentiality, Li argues that Chinese characters not only efficiently serve as a tool in recording the language, but more importantly, they fit the structural features of the language whose grammatical structure is based on independently standing roots. By nobility, it means that China's well-entrenched ruling class wanted to monopolize writing for its own advantages. "They fear (consciously or unconsciously) that if writing were simplified, everyone would be able to write. Writing would lose its dignity and they too would lose their dignity." Therefore, they maintained the character writing at the semantic + phonetic level. Considering that feudalism lasted 2,000 years in China, during which there was no spelling change taking place after Qin and Han, this explanation is quite reasonable. The combination of these elements as well as those discussed above all contributed in arresting Chinese writing at the logographic stage.

Evidence of Phonological Change

The orthography of a writing is usually more or less representative of the sounds of the language. Since writing is more conservative than speech, the orthography usually retains the features of older sounds, which have since centuries ago changed (Chao, 1968). To understand these changes and features, a knowledge of phonology, especially historical phonology, is quite essential. The successful reconstruction of the 7th century and even earlier Chinese phonetic system (e.g., Karlgren, 1947; Pulleyblank, 1988) has made it possible fo. us to have a clear picture of how Middle Chinese was pronounced in the past. It is often heard that sound changes have obscured phonetic representation in Chinese characters, but little systematic studies relating phonology to orthography are available. In this section I will show how sound representation in Chinese characters was obscured in the phonological evolution by tracing the changes of some characters. Implicit in the illustration is that change of phonology may take place independently of orthography.

In the course of evolution, Chinese has always tended to sound simplification. According to Karlgren (1962), about 800 B.C., there was still a considerable sound variation so that the homophones were not confusingly numerous. But as early as 500 A.D., the language tolerated no more than one consonant at the beginning of the word (with the single exception of certain "affricates": ts, dz, ch dj—phonemes that can be regarded as simple sounds). The same occurred to the final sounds of the syllables (e.g., every Chinese character at that period had to end either in a vowel or in p, t, k, m, n, or ng). But dramatic change of sound did not really occur until after 600 A.D. when Chinese was further advancing in sound simplification, and from then on, shifted from Middle Chinese to modern Chinese. Before Qie-Yin (a rhyme dictionary compiled in 601 A.D.), the Middle Chinese sound system distinguished 4 tones, 36 initials and 293 finals (of the 293 final, 160 are segmentally differentiated Middle Chinese finals, and 133 are tonally differentiated finals). After the change, the number of initials and the number of finals have been reduced from 36 in Middle Chinese to 22, and from 160 to 36, respectively, in modern Beijing, a dialect on which standard Mandarin is based. But, perhaps, the most important change in reshaping the sound pattern of all contemporary Mandarin dialects is the Great Vowel Shift (see below), which has left its marks on all the dialects of Chinese.

The MC Great Vowel Shift

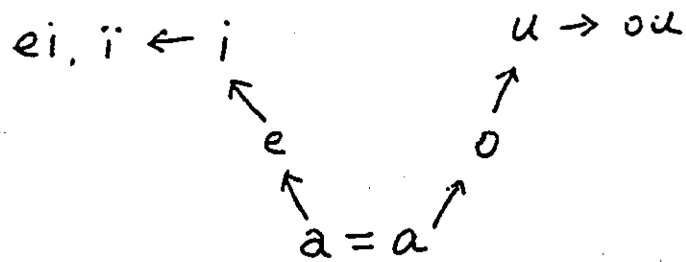


Table 4

The phonological processes that are considered to have taken place between Middle Chinese and modern Beijing have been described in great detail by Chen (1976), and I will not repeat them here. I will, instead, try to apply these rules and show how rule interactions during the changes gave rise to phonological residues.

In general, phonological rules stand in an input-output relation that is strictly successive (or complementary). A given rule can only either precede or be preceded by another rule, there being no third alternative. But since each phonological change has an internal time dimension, it is possible that two or more phonological processes could co-occur or overlap each other along the time dimensions. Thus, in addition to successive time relation, sound change could be also considered as "coincident, incorporating and overlapping" relation with each other (Chen, 1972). These non-complementary types of time relations, also called "intersecting changes" (Wang, 1969), may co-occur in time with or without interfering with each other.

It is assumed (Chen, 1972) that words change their pronunciations by discrete, perceptible increments (i.e., phonetically abrupt), but severally at a time (i. e., lexically gradual). In other words, when phonological innovation enters a language it begins as a minor rule, affecting a small number of words. As the phonological innovation gradually spreads across the lexicon, however, there comes a point when the minor rule gathers momentum and begins to serve as a basis for extrapolation. At this critical cross-over point, the minor rule becomes a major rule, and we would expect diffusion to be much more rapid. The change may, however, reach a second point of inflection and eventually taper off before it completes its course, leaving behind a handful of words unaltered. This seems to be exactly the case in Chinese if we look at several phenomena that are connected to the existence of residues.

(1) Sound changes take varying periods of time for their operations. Most sounds may change from X pronunciation to Y pronunciation directly without intermediate stages. It is possible that during the early phase of change only one or a small section of relevant morphemes is affected. For example:

黃	簧	潢	璜	磺	蟥	橫	
'yellow'	'spring'	'decorate'	'jade'	'sulphur'	'leech'	'horizon'	
*ɣuan̂	*ɣuan̂	*ɣuan̂	*ɣuan̂	*ɣuan̂	*ɣuan̂	*ɣuan̂	MC
–	–	–	–	–	–	ɣan̂	U-DELET
–	–	–	–	–	–	ɣain̂	VOCAL
ɣuaŋ	ɣuaŋ	ɣuaŋ	ɣuaŋ	ɣuaŋ	ɣuaŋ	ɣaiŋ	FUSION
–	–	–	–	–	–	ɣɛŋ	COALESCE
ɣ'uaŋ	ɣ'uaŋ	ɣ'uaŋ	ɣ'uaŋ	ɣ'uaŋ	ɣ'uaŋ	ɣ'eŋ	ASPIR
x'uaŋ	x'uaŋ	x'uaŋ	x'uaŋ	x'uaŋ	x'uaŋ	x'eŋ	DEVOEC
xuaŋ	xuaŋ	xuaŋ	xuaŋ	xuaŋ	xuaŋ	xeŋ	REDUNT
/xuaŋ/	/xuaŋ/	/xuaŋ/	/xuaŋ/	/xuaŋ/	/xuaŋ/	/xeŋ/	Beijing

(2) The longer a sound change takes the more likely it is to encounter a competing sound change. One consequence is that some of those affected morphemes that have changed to the Y pronunciation may still, or at least at first, have both the X and the Y pronunciations due to other sound changes that come into the procedure to compete for the same morpheme relevant to the X - to - Y change, therefore fluctuating either randomly or according to some such factors as tempo or style (i.e., literary vs. colloquial). For example:

薄

MC	*pak	MC	*pak
VOCAL	pauk	VOCAL	pauk
APOCOPE	pau	COALESCE	pok
. .	—	APOCOPE	po
	/pau/	Beijing	/po/

角

*kak	MC	MC	*kak
kiak	SHARP	SHARP	kiak
kiauk	VOCAL	RAISE	kiek
kiau	APOCOPE	APOCOPE	kie
tšiau	PALAT	PALAT	tšie
/tšiau/	Beijing	Beijing	/tšie/

(3) The same subset of morphemes simultaneously involving several phonetic dimensions that are related to each other by phonological rules may leave behind residues that are dramatically different in pronunciation as a result of intersecting and competing changes:

纷 'confuse' 忿 'anger' 分 'to divide' 粉 'flour' 芬 'fragrance'		盼 'to look for' 拚 'to make up'	
MC	*pyen	*p'yen	MC
LABDNT	fyen	p'uen	MID-DISM (a)
* CHAMEL	fyən	p'yan	G4-MERGE
Y-SPLIT	fuən	p'uan	Y-SPLIT
MID-DISM (b)	fən	p'an	MID-DISM (b)
Beijing	/fən/	/p'an/	Beijing

(4) Some of the initially unaffected forms in their course of catching up with the innovating forms somehow tapered off and came to a premature end, leaving residues, and preventing them from running the full course:

责		债	
MC	*tʂac	*tʂac	MC
VOCAL, FUSION	tʂaik	tʂaik	VOCAL, FUSION
COALESCE	tʂek	tʂaik	DERET
* CHAMEL	tʂək	tʂai	APOCOPE
DERET	tʂək	—	—
APOCOPE	tʂə	—	—
* CHAMEL	tʂɤ	—	—
Beijing	/tʂɤ/	/tʂai/	Beijing

(5) A certain morphemes persisted unaltered along the whole course of the time dimension, even after the sound change had ceased to be operative. The rhyme of these "true

residues" usually could be vaguely perceived:

	欠 'owe'	坎 'edge'	砍 'chop'	欽 'admire'
MC	*k'an	*k'an	*k'an	*k'an
SHARP	k'ian	—	—	k'ian
RAISE	—	—	—	k'ien
RAISE	—	—	—	k'iin
DEGIMIN	—	—	—	k'in
PALAT	c'ian	—	—	c'in
REDUNT	tš'ian	—	—	tš'in
RETROF	tṣ'ian	—	—	tṣ'in
DERET	ts'ian	—	—	ts'in
Beijing	/ts'iaŋ/	/k'aŋ/	/k'an/	/ts'in/

If those discussed above are correct, some examples (e.g., 工 /kuŋ/ "work" which as a phonetic element is read /kuŋ/ in 讧.红.功.贡, /kaŋ/ in 缸,杠,扛, but /tsiaŋ/ in 江,豇) which are often used as a basis to argue in favor of the claim that Chinese characters have no or little cue to pronunciation are too superficial, for the variations of these words in pronunciation are due to phonological changes as shown in the following:

	工 讧 红 功 贡	缸 杠 扛	江 豇	
	*kan̄	*kan̄	*kan̄	MC
	kain̄	—	kain̄	VOCAL
	ken̄	—	ken̄	COALESCE
	kaŋ	kaŋ	keŋ	FUSION
* CHAMEL	koŋ	—	kiaŋ	G4-MERGE
RAISE	kuŋ	—	ciaŋ	PALAT
—	—	—	tšiaŋ	FRICAT
Beijing	/kuŋ/	/kaŋ/	/tšiaŋ/	Beijing

It is obvious that phonological information is encoded in Chinese characters. While some characters whose correspondence between the written and spoken forms is indeed obscured by diachronic processes, and the manner in which phonology is encoded and the extent to which pronunciation can be derived have become more indirect, it is also true that most remainders still provide a good guide to rhymes. A link between a written word and its spoken form in Chinese characters does really exist.

Chinese Characters as Significs

Using a signific together with a phonetic to make characters is a unique feature in character formation. While the role of the phonetic element in a character is often underestimated, the status of significs has long been recognized as an important tool in character classifications. As early as 120 A.D., a total of 540 significs had been used as character classifiers in *shuowen jiezhi* . This function as lexicographer's tool stayed until 17th century when they were pruned to 214, which were further reduced to 189 in Mainland China after 1956. Characters in a dictionary are first arranged according to the radicals and then within each radical according to the number of strokes. The advangage of arrangement in such a manner, if there is one, is that items belonging to the same semantic category form a set and that the role of additional element is to distinguish one item from the other in the set (Yau, 1983).

A Dual-function Role

Significs are a product of disambiguation. They serve to disambiguate among homonyms and provide a direct cue to the likely meaning of the word on the other. In Chinese, completely or largely homophonous syllables written with a common phonetic can be distinguished in meaning by different radicals. This is different from English in which homophonous words such as *rain*, *rein*, *reign* etc. are distinguished by different spellings, but the disambiguating procedure is largely the result of historical changes in pronunciation as in the case of "knight" vs. "night". The disambiguating technique in Chinese, however, appears to have been created deliberately: take the character 來 /lai/ for example, 來 was originally a pictograph meaning "wheat" and was later used as a rebus symbol to represent the sound of the homophonous syllable meaning "come". Subsequently the original use was abandoned. But the new function as a syllable symbol received a further extension. Apart from its independent use in the meaning "come", it also came to be used as the phonetic element in the semantic + phonetic component 徠 /lai/ "come"—that is, with the addition of radical 彳 . The rebus use of the character 來 received still another extension when the graph entered into the semantic + phonetic component 萊 /lai/ "thistle"—that is, with the addition of radical 艹 "grass". Here, the character 萊 has lost both its original meaning of "wheat" and its secondary meaning of "come" and is further used purely in its syllabic value to indicate the pronunciation of still another homophonous but semantically unrelated word. "Such a disambiguating technique", as Defrancis (1984) notes, "in which many complex significs are joined with even more numerous and perhaps even more complex phonetics undoubtedly provides better visual clues to the characters."

The dual function of significs in disambiguating among homonyms and cueing meanings perhaps may be clearly illustrated in the following examples involving 馬 :

1. 媽 /mā/ mother
2. 嗎 /mā/ question marker
3. 罵 /mà/ scold
4. 碼 /má/ marked chops
5. 螞 /mǎ/ residue prefix for insects

In these examples, 馬 as a phonetic indicator is the common denominator, for each word's phonetic realization is a homonym of /ma/. In (1) the semantic indicator 女 means "female"; in (2) 口 means "mouth"; in (3) there are two instances of 口 ; in (4) 石 means "stone", and in (5) 虫 means "insects". In each of these words a semantic indicator has been added to 馬 . The function of 馬 , however, changes in the following set of examples.

6. 駘 /tai/ inferior horse
7. 驥 /ji/ stallion
8. 駕 /jia/ to ride

9. 駒 /ju/ gelding

10. 驢 /lu/ donkey

In these examples, 馬 is the semantic indicator. 台，冀，加，句，盧 are the phonetic indicators of /tai/, /ji/, /jia/, /ju/ and /lu/ respectively in (6), (7), (8), (9), and (10). In each case, 馬 serves to distinguish the particular items from other homonyms or near homonyms, as the semantic content of each of the phonetic indicators has no semantic significance in the symbol.

What may be said after illustrating this dual-function role of significs is that significs have existed for 2000 years and clues to the meaning of characters provided by the radicals should, thus, be followed with caution. For example, the mouth radical 口 is useful in identifying 吃 "eat", 喝 "drink", or 吻 kiss", but it is of no help in identifying 噸 "ton". Some radicals may stay meaningfully firm in the character which takes them, while some may be downright misleading (e.g., how does 菩薩 /pusa/ "Bodhisatva" have anything to do with grass " 艹 "? Is 虹 "rainbow" a kind of 虫 "insect"?). As a matter of fact, significs in predicting meaning, as noted by Defrancis (1984), are less superior to phonetics in predicting pronunciation. In a study, he showed that the purely semantic characters comprising only a tiny minority of all Chinese characters (3%), and that in the major category of semantic + phonetic characters (97%), the phonetic elements are superior in cueing pronunciation than the semantic elements in predicting meaning.

The role of the semantic aspect of the Chinese characters is often overemphasized, because people used to think that Chinese writing is pictographic or indeographic, evoking mental image or presenting ideas to the mind entirely independent of speech. Our discussion so far should have ruled out this misconception. What seems to be true is that Chinese writing is an orthography in which the relation of symbol to meaning is mediated primarily through a sound system based on a defective inventory of syllabic signs and quite secondary through a semantic system based on an even more defective inventory of significs (Defrancis, 1984).

A Mirror to Ancient Culture

In his recent paper, T'sou (1981), in an attempt to uncover from the system of classification of the universe implied in the use of the 214 radicals, shows that there is an imbalance between masculine and feminine categories, and this might be due to matrilineality society in prehistoric Chinese society. According to his examination, most of 214 radicals fall into 4 natural classes: Nature, Flora, Faura, and Man:

A Semantic Scheme for the Classification of Radicals

1. **Nature**
   - a) The elements
   - b) Terrestrial/geography
   - c) Extra-terrestrial
   - d) Mineral
   - e) Time/periodization
2. **Flora**
   - a) Cereal/grain
   - b) Botanical/agricultural product
3. **Fauna**
   - a) Animal
   - b) Body parts exclusively from animal
4. **Man**
   - a) Organs and body parts
   - b) Human
   - c) Implements
     - (i) for survival (weapon)
     - (ii) for livelihood (tools/utensils)
   - d) Mortality and beyond
     - (i) life cycle
     - (ii) supernatural/worship
   - e) Agriculture
   - f) Food
   - g) Clothing (and ornaments)
   - h) Dwelling
   - i) Locomotion/transportation
   - j) The faculties
     - (i) sight and color
     - (ii) smell and taste
     - (iii) perception and measurement
   - k) Socialization
   - l) Communication
   - m) Other human activities

Table 5

The largest class is "man", which accounts for about 65% of all items. While under Human, the number of Chinese characters classified under 女 "female" was one of the largest: there are 258 characters under this radical in *shuowen jiezhi*. The number has only been reduced over 180 in the modern *xinhua zhidian*, which contains about 8,000 most common characters. This means that close to 2.3% of the most common words in modern Chinese are classified under "female". This is in marked contrast to the male category, which had only three words (男 "male", 甥 "nephew or niece on the maternal side", 舅 "maternal uncle"). A survey of the entries for 女 in a modern dictionary reveals several interesting facts:

(1) The consistently occurring 女 radical for three generations of maternal female co-sanguineous relatives (e.g., 婆 "maternal grandmother, 姥 "maternal grandmother", "maternal grand-mother", 媽 "mother", 娘 "mother", 姨 "aunt", 姐 "older sister", 姊 "older sister", 妹 "younger sister") versus the inconsistently occurring paternal uncle relatives (e.g., 爷 "paternal grandfather, 爸 "father". 父 "father" 伯 "older uncle", 叔 "younger uncle", 兄 "older brothers", 弟 "younger brother") shows that the structure of maternal/ female co-sanguineous kinship relationship has a longer history and greater importance than the corresoponding paternal uncle relatives. all of who share the same surname in a paternal society.

(2) Important concepts relating to lineage are classified under the radical 女 : for example, 始 "origin", or 姓 "surname".

(3) Historical figures whose origins are shrouded in mythology had archaic surnames with the female radical: for example, 姬 for 黄帝 , 姞 for desendants of 黄帝 .

(4) Words pertaining to marriage or more basically to the formation of couples or family use radical 女 , indicating a tilt towards the female side. For example, 媳 "daughter in law", 婿 "son in law"; 嫁 "marry-to take husband, 娶 "marry-to take wife"; 婚 "marriage", 媒 "marriage-broker".

If these words associated with matriarchy which are of considerable antiquity can be taken as rare residual evidence of the social structure of China at the time the writing system was developing, concluded T'sou, then female primacy is not a recent innovation but is associated with origin of the writing system in the prehistoric past.

Summary

All writing represents language in some of its elements, words, syllables, or simple sounds. Chinese characters represent morphemes, and they represent them phonetically for the most parts, despite their diverse technique and differing effectiveness in accomplishing the task.

Every character in Chinese has a form, a sound and a meaning, each of which has undergone great changes over the centuries. As a result, Chinese characters which symbolize old pronunciations are no longer appropriate enough for modern pronunciations. The so called semantic function in Chinese characters is not always carried out by truly semantic contribution from the semantic element. In fact, semantic elements in predicting meaning are far less valid than phonetic elements in predicting sound. Overestimation of the role of semantic elements may be attributed to the first three character-formation principles which are semantic in nature.

Despite all the changes throughout the history of written Chinese, there is one aspect in which the relationship between graph and word has not changed: every symbol continues to correspond to a single syllable. Such a syllabic value of the phonetic is of such overriding importance that the Chinese writing should be considered as "morphosyllabic". The essence of its being the syllabic type is not merely at that each character is pronounced as a syllable, but that the pronunciation of the character is obtained through the intermediary of component syllabic symbols, namely, the phonetics.

CHAPTER 3

Visual–Hemispheric and Cognitive Processing of Chinese Characters

Reading research has attracted attention from experimental psychologists and cognitive neuropsychologists over the past three decades. The problem has been attacked from different perspectives with various experimental and clinical paradigms, such as recording patterns of the eye movement and relating them to various phases of information pick up, studying patterns of deficits manifested in the reading performance of various types of dyslexic patients and specifying the specialization of the both cerebral hemispheres, or looking into specific characteristics of word perception and attempting to build interactive models of human information processing. In this Chapter, I will look at each of these issues, in turn, and attempt to discuss them in relation to Chinese character processing.

Visual Processing of Chinese Characters

When reading text, the eyes do not move smoothly and continuously as casual introspection might suggest. They actually move in a series of discrete, ballistic jumps known as saccades. In between saccades, the eyes are relatively steady, focusing on a particular point in the text for periods of time called fixations. The saccades vary substantially in length, but average about seven to nine English characters, and take roughly 15-30 msec. to accomplish, depending on the length of the saccades. Fixations are also highly variable, but last roughly 200-250 msec. on the average. Virtually all the information extracted from the text is acquired during the fixations. In addition to eye movements that advance the eyes forward through the text, there are return sweeps that move the eyes from the end of one line of text to the beginning of the next line and regressions that move backward through the text rather than forwards. Regressions account for 10-15% of the movements during reading; most are only a few characters in length and are, for the most part, unconscious made without the reader noticing them (see Rayner, 1983).

Eye movements reveal cognitive processes; they are sensitive to the real time text material. Their pattern of moving during reading differs from orthography to orthography. At the early stages of initial processing, these differences in number of saccades, fixation durations and visual involvement are usually referred as low-level differences in information processing. Recently, it has been suggested that visual processing plays a distinctive role in remembering and processing Chinese characters. To begin with, let us first look at eye movements in reading Chinese.

Eye Movements in Reading Chinese

Eye movements in reading Chinese are slightly different. Chinese characters are suitable to both horizontal and vertical directions of reading, because a one or two-character word is well within a horizontal as well as a vertical perceptual span. Vertical alignment in general compares favorably with horizontal alignment, but some readers who are used to vertical alignment may find it somewhat less comfortable to read a text arranged horizontally. In a study done in the United States, Chinese readers averaged 10 saccades per line in reading a Chinese text, compared with American readers who averaged 4 per line, though both Chinese and English texts were written horizontally in the same width. Fixation durations did not distinguish the two groups (Stern, 1978). In another study of reading English (F. C. Wang, 1935), Chinese students made 10 saccades per line of print with many regressions. This similarity in saccades suggests that Chinese readers were reading English the way they read Chinese. There are several accounts for the smooth but more frequent eye movements in reading Chinese than in reading English: (1) Each character is of a similar size and occupies the same amount of space regardless of the number of strokes (F. C. Wang, 1935). (2) This uniformity of characters causes other striking differences in the spatial distributions of fixating a long line; the square shape of the characters and their compact arrangement in a line demand smaller and more frequent eye movements than is required in the reading of

English (Shen, 1927). (3) Almost every character in Chinese is meaningful and important, and hence, needs processing. Compare the sparse and lean sentence "know person not say, say person not know" to its English equivalence, "He who understands does not talk, and he who talks does not understand." The English sentence contains more items, in which function words such as does, who, and, the suffix -s are usually skipped during reading (Taylor and Taylor, 1983). (4) Chinese readers do not make much use of peripheral vision, since characters are by and large uniform in gross appearance and there are few prominent features to be noted in peripheral vision (Taylor and Taylor, 1983).

Visual Density and Visual Involvement

Chinese characters are visually dense. In a writing system in which there are several thousand characters, some characters have to be complex to ensure that they can be discriminated from one another. Of a character, the graphemic components which are made up of a variety of strokes applied in a relatively fixed order are assigned within a square frame. This frame in most cases is itself partitioned in a number of different ways, with components occurring side by side, in horizontal layers, in quardrants, etc. (Fok and Bellugi, 1986). With the result that the more strokes a character contains, the denser its configurations and stroke arrangements are. To print a Chinese character as configurations of dots on a display screen takes a 50 x 40 dot matrix, while a 7 x 11 dot matrix is often enough for alphabetic letters.

Characters with more strokes, intuitively, should be harder to perceive than those with fewer strokes. Studies show that recognition threshold is longer for complex characters (15 or more strokes) than for simple ones (10 or fewer strokes) (Yeh and Liu, 1972). Of the characters with 11-15 strokes, some may be relatively easy to perceive, while some may not, depending on the structure (Ai, 1955). According to Ai, characters were often hard to read when they had more than 13 strokes total and the difference in the number of strokes of the left and right components was greater than 10, or the character composed of several clusters of strokes. More recently, Just and Carpenter (1987) observed that the amount of time that Chinese readers spent on each character increased linearly with the number of strokes, and that the average gaze duration increased reliably by 4.6 msc. for each additional stroke. This suggests that decomposition occurs when a word is visually complex.

Given this complexity, one may wonder whether Chinese readers assimilate the orthographic characteristics of the writing system in reading. That is, if they know that the configuration of a logograph is important in deciphering it, they must pay special attention to the position of every element it contains during reading. If they do, the processing of Chinese characters should involve more visual memory than the processing of alphabetic script, and visual perceptual processes may play a more distinctive role in perceiving Chinese characters than in English. Recently, Tzeng and Wang (1983) compared the memory performance of native English speakers and native Chinese speakers. They presented a series of nine items to subjects either auditorily with a tape recorder or visually by means of a slide projector. In the visual presentations, the items were in either English words or Chinese characters. The subjects were asked to recall the nine items according to their positions in the series, and the probability of recall was plotted according to the item's position. The resulting data from both groups of readers in the study show that strong visual effect occurs with the last two items. The interesting difference between the two groups is that the Chinese readers recalled the other items in the series consistently better when they were presented visually rather than auditorily, whereas no such difference was found for the English readers. Visual presentation was superior for Chinese readers regardless of whether they were asked to recall the items orally or in writing. The result suggests that processing Chinese characters involves more visual memory than does processing alphabetic letters. This greater involvement of visual memory in Chinese character processing corresponds to what is found in Tachistoscopic experiments which show that the right hemisphere is more active in processing Chinese characters and that Left Visual Field superiority is always obtained during the first 50 msec. of a fixation.

Sensitivity to Character Structure

Orthographic structure facilitates perceptual recognition (Massaro, 1980; Barron, 1981). Given a nonsense letter string like *ohrdc* and a pseudoword *dorch*, one may find it easier to read aloud the latter than the former, because the latter looks more like a word, even though neither of them has a lexical meaning. This difference between these two nonwords in pronounceability and appearance suggests that pseudowords are generally more consistent with orthographic constraints and have higher positional values than letter strings and that it is easier to recognize. It also suggests that readers are capable of using their knowledge of English orthographic structure without necessarily translating the items into phonological representations. Use of visual-orthographic structure can also be found in other studies such as visual search, word likeness, lexical decision and visual matching tasks, in which children as early as they are between the second and fourth grades seem to be able to use some of the gross characteristics of orthographic structure in word recognition (see Barron, 1981).

Chinese characters consist of constituent components. Each individual component has a specific place in the spatial layout. Semantic components usually appear to the left or at the top, while phonetic components appear in the complementary position to the right, or at the bottom. Experiments show that subjects are sensitive to the orthographic convention, and that they make use of constituent components during reading. In Tzeng and Hung (1980)'s experiment, for example, Chinese subjects read a passage, circling all characters containing certain grapheme components. The subjects detected more characters in which the designated grapheme component was a phonetic than characters it was not a phonetic. In Kuo (1923, cited in Taylor and Taylor, 1983)'s experiment, American college students learned the English meanings of several characters containing the same radical. Each student then was questioned to ascertain whether he had noticed the radical, and divinced its meanings of the characters in which it was part. Though instructions made no reference to radicals, the majority of the students not only showed notice of radicals but spontaneously discovered the meaning of "mouth". In Taylor (1980)'s experiment, two characters sharing a radical tended to be grouped as being similar in meaning when possibilities for pairing by meaning or by sound were available; whereas two characters sharing a phonetic tended to be grouped as being similar in sound.

Stronger evidence of sensitivity to visual-spatial aspects of character formation, that is, its architecture, its components and their arrangement, its spatial layout, and even configurational aspects, comes from errors made by deaf children in learning to write. In Fok and Bellugi (1986)'s study, they found that deaf children who have no phonological clues to words to hold onto relied primarily on their knowledge of orthographic rules extracted from their knowledge of characters. In the process of learning to write, deaf children not only actively discover the internal regularities, they also make use of such regularities in creating new character forms. In their invented characters, Fok and Bellugi found that over 90% of them were well formed characters, that is, conforming to the structural rules of existing Chinese characters. For example, the error word  was written instead of the character 醫 meaning "medical". Both the error and the target have the same architectural forms  . The top pieces on the left of the two words are identical whereas the top pieces on the right are different but resemble one another closely in shape. The bottom piece of the error  , however, is a non-existing form which again resembles the target " 酉 " very closely.

Such error patterns which are always perfectly acceptable character forms following all the implicit rules of character formation suggests that visual aspects play a dominant role in character learning. By the time the strategy in which characters are learned from the whole, to the differentiation of the whole, and then to the synthesis of the parts to a more meaningful whole is taught, readers's sensitivity to orthographic structure is well tuned, with the result that sensibility becomes automatic during reading.

Extraction of Visual Features

A feature is some characteristic of an object that puts it into a class with one set of things and differentiates it from another set (Taylor and Taylor, 1983). Chinese characters may consist of two kinds of features: fragmental features (also called simple features) and configurational features (or juncture features). A fragmental feature is a mark of a character, such as those in dots, hooks and lines which are respectively a building block for the whole character. A configurational feature depends on the relationship among the fragmental features which are junctured and positioned within the square, such as those which form parts of West/East, North/South, etc.. In reading, configurational features are important, they are used more often than fragmental features to recognize characters.

Features of characters may be described abstractly and arbitrarily. Each character, if enough different features are described, may be uniquely identified by the set of features it has. For example, the only character that is square, closed and without inner parts is "口". 日 shares all these features except "a central cross-bar". Characters that own a feature that others lack may make themselves easily discriminable. Such features, which discriminate themselves well, are usually called effective features. Effective feature lists which anyone can make to describe sets of characters, however, may not necessarily the recognition feature lists which people actually use in word recognition. According to a study done by Kaiho and Innkai (1982, in Taylor and Taylor, 1983) who asked 554 subjects to rate the 881 Kanji characters taught in primary school on ten descriptive dimensions, three major factors seem to be important in the recognition of Japanese Kanji: (1) symmetric characters with long or rectilinear strokes versus asymmetric characters with short and diagonal strokes. (2) Open characters with few strokes versus complex dense characters. (3) Elongated versus square or round characters. Other studies (e.g., Healy, 1981) show that "inner parts are less important and have lower weight than outer shapes in scanning a text for misprint. This observation, as Keren and Baggen (1981) suggests, reflects the nature of the perceptual processes where global features play a more important role.

In feature detection, there are two mechanisms which are crucial: the fovea and the parafovea. In focussing on a word, the fovea of each eye is directed to it, the fovea subtends about two degrees of visual angle around a central point of fixation, which covers a span of 7-10 letter spaces. Adjacent to the fovea is the parafovea that subtends about 16 letter spaces on either side of the fovea. While the entire fovea is used in reading, only part of the parafovea is useful since acuity in the parafovea is much poorer than that in the fovea. Studies show that a fixation at a time can cover a span of at least 2.5 Chinese characters or 1.6 English words (Just and Carpenter, 1987) in a saccade in normal reading. Fixation implies foveation; if the useful part of the perceptual span that the parafovea extends — which is about 10-20 letter spaces— is taken into account, then, in feature extraction, global feature information such as length, shape of a character and blank spaces between characters is picked up parafovealy while precise internal details are dealt with fovealy, both registering at exactly the same time and interacting when a word is exposed, perceiving wholistically from the outside inward, since the perceptual span of the parafovea is in any case larger than the fovea, and therefore, is always faster. In Keuss's (1977, cited in Taylor and Taylor, 1983) study, he observed that the outshape tends to be detected much faster than the orientations of the inner lines due to the wider perceptual span, and that it interferes with detection of the lines oriented. Taylor and Taylor (1983) also note that outshapes are perceived first, and that the internal features, with adequate view time, can be clearly seen. According to them, internal features are usually not necessary, because before they can be seen, the word has been identified from its gross configurational features. This seems plausible since the whole process of encoding visual information necessary for word recognition occurs during the first 50-80 mesc. of a fixation (Rayner and Duffy, 1988; Just and Carpenter, 1987).

The very initial perceptual processing, presumably, is done by a series of feature detectors, starting in the retina and continues in central processing mechanisms. A feature detector responds to some property of its input, if the input pattern looks like the one to which the detector is tuned, it will respond strongly; otherwise, it responds less strongly. For example, in detecting a Chinese character, simple-feature detectors respond to features such as those in dots, hooks and lines; juncture detectors of simple features act as a mechanism for fusing the simple features into a higher-order features assemblages, that may correspond to clusters of strokes; configurational position detectors of features assemblages are sensitive to the positional information within the square (e.g., the positioning of 口 and 木 in 杏, 呆). Once the process of feature detection has resulted in an interpretable perceptual representation, feature detectors transform the pattern information from the type of pre-cognitive representation into a word-like level representation (see Johnson, 1981), where detectors may interact with one another from outside in (McCuster et al., 1981) through mutual inhibition and by feedback from high levels (Taylor and Taylor, 1983). The whole processes of feature detection are complete by 50 msec. (Lupker, 1979), although character recognition may not always be. The completion of feature detection forms an abstract code for lexical access.

Hemispheric Processing of Chinese Characters

An emerging perspective in reading research is studies on pattern of deficits manifested in the reading performance of various types of dyslexic patients. An interesting observation is that the patterns of reading disorders depend not only on the location of brain damage but also on the typology of the writing system. Such an observation has led many investigators to conclude that lexical access of words written in different orthographies (e.g., alphabetic vs. logographic) is accomplished by different neurolinguistic pathways of the two cerebral hemispheres. For example, Henderson after an extensive and critical review of the literature offers a tangible dichotomy based on the specialization of the two cerebral hemispheres, in which he assigns the reading of Chinese characters to the right hemisphere (Henderson, 1982, in Tzeng et al. 1986). In this section I will first review some relevant data challenging this hypothesis and then discuss the hemispheric activities in processing Chinese characters.

Against the Hypothesis of Right Hemispheric Representation of Chinese Characters

Throughout the history of hemispheric specialization research, there has been speculation that hemispheric functional specialization may be related to the type of written script one has acquired in learning to read. Hinshelwood (1917, in Hasuike et al. 1986) claimed that the ideal therapy for patients with the syndrome of word-blindness was to teach them Chinese characters because, according to him, Chinese was a script in which each word was represented by a different symbol. This claim was supported about 60 years later by Rozin et al. (1971) who report success of teaching dyslexic American children in reading English representation of Chinese characters (but see Tzeng and Hung (1981) for a critique of this study). Recent findings of selective impairments in the reading of Kanji script by Japanese aphasic patients within a single spoken language have further strengthened the hypothesis of the scriptal effect on cerebral organization (Sasanuma, 1980; Hung and Tzeng, 1981).

To challenge the hypothesis of right hemispheric represention of Chinese characters, we need to look at two things: its reasoning and empirical basis. There are basically two reasons why Chinese characters are thought to be processed by the right hemisphere: (1) Chinese characters lack grapheme-phoneme correspondences (GPCs). Recognition of Chinese characters, therefore, does not require the use of the so called grapheme-phoneme correspondence rules which presumably are employed by the left hemisphere to decipher the printed symbols. (2) The spatial layout of Chinese characters determines that the recognition should be handled better by the right hemisphere which presumably specializes in visual-spatial processing (see Tzeng et al., 1986).

With respect to the first reason of lack of phonological recoding in the visual processes of Chinese characters, a number of studies have successfully demonstrated that there is phonological recoding in reading Chinese characters (see the end of this Chapter for a detailed discussion). The remaining question is how this phonological recoding process can be accomplished since Chinese characters do not have the clear grapheme-phoneme correspondence. As was discussed in the previous Chapter, readers of Chinese can in fact make reasonably successful guesses about how to pronounce characters that share the same phonetic component, even when they encounter characters that they have never read before. The procedure involved in this type of grapheme-sound conversion may be different from that involved in the GPC rules, but is similar to Glushko's (1979) naming by analogy (see Chapter 4 for discussion). Coltheart and Funnel (1987) suggest that it is possible for orthography to map onto phonology at the whole word level.

Supportive evidence against this reason may also be found from clinical data. Of the main clinical data discussed by Hasuike et al (1986), there is strong evidence suggesting that the right hemisphere is not involved in the processing of Chinese characters: (1) Some left hemisphere-damaged aphasics are reported to be selectively impaired in reading Kanji. Tatsumi et al. (1982, in Hasuike et al. 1986) showed that the majority of their seventeen patients could identify kana symbols more easily than kanji ones. (2) There is no strong evidence for a relationship between right hemisphere damage and impairment of kanji. Of the cases, since 1901, of dyslexia in Japanese readers, five had right hemisphere damage. Of these five, only one patient performed better with Kana than with Kanji; three cases showed better performance with Kanji than with Kana, and one showed no difference between the two. (3) There are a few cases where there is a differential impairment of Kanji and another type of "logographic" script, namely, numerals. There were patients who could not read numbers while preserving ability to read Kanji, or who could name Arabic numerals but had great difficulty reading Kanji characters. A Chinese patient (Lyman, et al., in Hasuike et al., 1986) could not read Chinese but could recognize numbers.

The other reason for associating the processing of Chinese characters with right hemispheric functions is even less adequate than the first one. Because of their unique spatial layout, Chinese characters have been regarded as something like pictures and thus being processed in the right hemisphere. Evidence backing this reason comes from visual hemifield experiments. Hatta (1977a) showed that native readers of Japanese identified singly presented Kanji characters better when they were presented in the left visual field than in the right visual field. In his previous study (Hatta, 1977), a reverse pattern had been observed for the identification of Kana symbols. Hatta's new finding was in accord with results obtained by Sasanuma et al. (1977). These researchers presented nonsensical two-character Kana and Kanji words to native Japanese readers and found a significant right visual field superiority for the recognition of Kana symbols and a nonsignificant left visual field superiority for Kanji characters.

In a similar vein, Segishita et al. (1978) reported three cases and Watanabe et al. (1979) described two cases of patients who had undergone a surgical section of the splenium of the corpus callosum, thus partially isolating the two hemispheres. Careful examination of the performance of these five patients on a visual hemi-field paradigm to compare the recognition of Kanji and Kana characters presented directly to the right or left hemisphere revealed minimal recognition of Kanji in the right hemisphere. These findings were interpreted as evidence for right hemisphere involvement in processing Kanji characters (Hatta, 1980).

However, using a standard tachistoscopic visual half-field presentation with Chinese brain-intact subjects, Hardyck, Tzeng and Wang (1977, 1978) obtained a right visual field superiority for the recognition of Chinese characters. In Besner et al.'s (1982) experiment, they looked at Chinese and Japanese subjects' performance with both Arabic and Kanji formats for numbers. The results show that both formats yielded a right visual field advantage, contraditory to the hypothesis that single Chinese characters are exclusively identified by the right hemisphere.

The obvious problem raised by these controversies concerns how it is possible to account for the fact that some Chinese characters yield a LVF advantage while others produce a RVF advantage. A critical review of relevant literature (Hasuike, et al, 1986) suggests that the observed LVF advantage may be due entirely to perceptual factors and may have nothing to do with linguistic processing. In their survey of twenty studies with Chinese characters as stimuli, a LVF superiority was found only in those studies in which the exposure duration was less than 50 msec.. When the exposure duration was over 50 msec., a RVF superiority was found.

Exposure duration is a crucial factor in influencing the pattern of visual field asymmetries. Brief exposure durations result in an incomplete visual image with a very low spatial resolution. The right hemisphere seems to be adept at perceiving the relationship between fragmentary components and the whole configuration. When the stimulus is presented for a longer exposure. spatial resolution is better. Under such conditions, the left hemisphere seems to take charge (Hasuike et al., 1986). This may be associated with strong visual involvement that we discussed earlier.

The fact that Chinese characters are not processed in any picture-like fashion can also be found from the writing errors committed by patients suffered from either right or left hemisphere damage. In Tzeng et al.'s (1986) study, two patients, one with right hemisphere damage and the other with left hemisphere damage, were asked to perform copying tasks: one including geometric graphs, pseudo-characters and non-characters; the other including drawing pictures upon hearing the names of the objects, writing down multi-character words according to the names of pictures and constructing sentences as instructed by the tasker. It was found that it is the left hemisphere, not the right hemisphere, which plays a dominant role in the writing of Chinese characters. The right hemisphere damaged patients showed typical signs of visual neglect in the left visual field, but in writing or copying characters the patient never missed any component-graph on the left hand side of a character. This provides unequivocal evidence against the proposition that because of its picture-like characteristics, Chinese characters are represented in the right hemisphere. The so called orthographic specialized localization after this discussion seems apparent than real.

What should be noted also, as we are dealing with lateralization, is another extreme which claims that RVF advantages tend to be found for two-character words, because two character words involve sequential processing. A recent study (Keung and Hoosain, 1989) has cast doubt on the claim. In the study, they produce evidence, for the first time, of a right hemisphere advantage for two-character Chinese words, under the condition of reduced visual energy with short exposure duration and low luminance while the stimulus items had low frequency of usage and high visual complexity. Although perceptual factors may be responsible for all these findings of right hemisphere advantage, they also suggest that linguistic factors (e.g., a character is both a visual syllabic and meaning unit) can still play a part, because all types of English linguistic materials, from single letters to syllables, letter strings and words, seem to always show left hemisphere advantage even with reduced stimulus energy as short as 4 to 9 msec. while single Chinese characters still obtain right hemisphere advantage even at a mean exposure time of 40 msec..

It seems obvious that Chinese characters cannot be picture-like in the sense of iconicity. In fact, a pictograph once it represents sounds is no longer pictoral; it is a linguistic symbol that requires verbal awareness for its processing. Such verbal awareness seems to be the property of the left hemisphere. The discussion in the following shows how the right hemisphere makes its contributions and how the left hemisphere cooperates with the right hemisphere in recognizing a character.

Hemispheric Specialization and Character Processing

In the Bilateral Cooperative (BLC) model developed by Taylor and Taylor (1983), reading involves two parallel streams or "tracks" of interacting processes. According to this model, the **LEFT track** deals with functional relationships, sequentially ordered material, phonetic coding, syntax, and most other linguistic functions. It is an analytic, slow and logical track. The **RIGHT track** performs pattern matching functions, seeks out similarities between the input patterns and previously seen patterns, evokes associations and relates the meanings of words and phrases with real-word conditions. Its functions tend to be wholistic, fast and automatic. And it is visually based. LEFT and RIGHT tracks cooperate in extracting the meanings from marks on a page. The RIGHT track makes quick guesses, and the LEFT corrects the guesses as well as linking the results into phrases, clauses, and large units.

Taylor and Taylor use LEFT and RIGHT tracks to distinguish left and right hemisphere processes. According to them, the LEFT processes are mainly restricted to the Left hemisphere; the RIGHT processes, on the other hand, can be performed by either hemisphere. The right hemisphere performs the RIGHT processes only when the left hemisphere is working on the LEFT processes. The capabilities of the right hemisphere limits itself from doing too much linguistic work. Zaidel (1978) observed that (1) the right hemisphere recognizes patterns through template matching which compares a pattern directly with a stored template, it uses no analytic rules but the whole input pattern, and the whole template globally; (2) the right hemisphere has very poor short-term memory and can relate no more than three or four content words; (3) Its comprehension is not impaired by syntactic complexity, but it has problems with longer strings of words; (4) it has neither phonetic coding nor grapheme-phoneme conversion rules.

Given the characteristics of the right hemisphere, one may assume that phonetic materials such as alphabetics and Kana are better identified by the left hemisphere than by the right hemisphere When an English word is presented, information about it builds up over time, both LEFT and RIGHT tracks turn the patterns of light and shade on the retina into visually features. This process is similar and identical in the two hemispheres, both working as a whole. When a Chinese character is presented, however, the same processes may occur, but the right hemisphere seems to be more active with visual features, and hence being particularly adept at the spatial architecture. The left hemisphere, which is analytic and phonetic, has access to the information and participates actively, its role, nevertheless, is minimized in comparison. In addition, to transform the information from one hemisphere to the other takes a finite time, and successful visuo-spatial transformation in the right hemisphere requires the presence of a preplanned organization of some familiar patterns. As a result, RVF superiority of the left hemisphere cannot be seen until 50 msec. or more.

When enough information is detected, a RIGHT detector, which sees patterns that look like the word to which it is sensitive, is likely to claim a recognition. A recognition in this manner is never absolute and is seldom unique, because the process is fast and admits substantial variations in the accepted forms.

A correct claim of recognition usually comes from the subsequent work of the LEFT track which admits only one reponse to a stimulus pattern. The LEFT track is able to deal with subparts of structures: it can analyze character components or extract the phonetics from characters. The major job of the LEFT track in word recognition is phonological recoding. It alone can translate between visual and phonetic representation of words, either by pattern matching or by analogy.

The specialization of the LEFT track is comprehensive, but it alone cannot recognize a word well. To work well and quickly it needs to work with the RIGHT. The RIGHT gives the LEFT some guesses to be checked, and checking the accuracy of a guess is easier than working about the solution of a puzzle from scratch.

In the initial stages of word recognition, following the BLC model, both tracks begin with visual processing of the patterns of marks on the page. The RIGHT track attempts a complete word recognition, whereas the LEFT looks for either words or part words. If the RIGHT track finds a word, it passes the meaningful elements to an associative, image-producing set of processes, while separating out the syntactic functions of the word for handling by the LEFT track. If the LEFT independently finds a word, it may do the same; if it does not, it can develop a phonological representation using subparts of the word. The result is a phonologically recoded version of the word. From this stage on, character processing is at its intermediate and advanced stages, the representation produced is analyzed syntactically by the LEFT and semantically by the RIGHT. Priming, associating, interpreting all occur together, but they remain simple when the LEFT and the RIGHT tracks are working cooperatively.

Cognitive Processing of Chinese Characters

Modelling the cognitive processes of word recognition has become a complex and sophisticated enterprise. The rapid accumulation of new data means that the phenomena to be explained, and hence the characteristics of the models themselves, are in a continual state of flux. There have been various models proposed for word recognition in the past three decades, and modifications have been kept making. Here, I will look at the models that are currently available, and then provide evidence from Chinese to support the position that cognitive operations involved in lexical access are similar across orthographies. In addition, I will also discuss how multi-character words are processed.

Routes to the Mental Lexicon: Lexical Instance vs. Dual-Route Models

Of the models of word recognition that are currently available, the lexical instance models and the dual-route models are the two most active and viable classes (Carr and Pollatsek, 1985), although the existence of independent lexical and non-lexical routes in word precessing has been challenged by Humphreys and Evett (1985). Before turning to these two major classes of models, a third species of model—phonological recoding— which thrived in the early 1970s but is now extinct is worth of a brief look in order to better understand the differences between the two major approaches.

According to phonological recoding models, activation of the meaning of a printed word can occur only if the visual presented string of letters is mentally recoded into a phonological representation. This representation is prelexical, meaning that it is constructed from knowledge of the generalizable rules that govern translation from grapheme or spelling patterns to phonemes or pronunciation patterns. Although these models are capable of recognizing printed words that are in a perceiver's speaking vacabulary but have not been seen before, they are incapable of correctly processing words whose phonological recoding are irregular with respect to normative generalities such as *one, two, shoe*, and they are incapable of dealing with families of orthographically related words for which it is simply impossible to find a strategy, such as the *ough* word (rough, though, through, cough, brought, drought). Furthermore, they cannot distinguish between strings of letters that are spelled differently but pronounce the same such as *there* and *their* (see Carr and and Pollatsek, 1985). More importantly, experimental studies have shown that visual codes can gain direct access to word meanings independently of phonological recoding. Gradually, the single-route theories died a natural death because they could not address large portions of the relevant data. The lexical instance models that have chosen to drop phonological recoding as a prelexical encoding process, and the dual-route models that have chosen to retain it as a complementary mechanism based on visual access distinguish themselves from other existing models (e.g., McClelland and Rumelhart's (1981) multi-level approach).

In general, the category of lexical instance models have a complicated internal structure. As opposed to phonological recoding models, the defining characteristic of the class is that its members depend on visual access to a memory system that represents individual words, rather than using general rules, in order to achieve recognition (Carr and Pollatsek, 1985). A lexical instance model, following Carr and Pollatsek, is one in which each word has its own separate representation in a memory system, and that representation is responsible for recognizing all occurrences of the word in print. In other words, a lexical instance is a prototype of a word (Smith and Medin, 1981, in Carr and Pollatsek, 1985)

The prototype-based lexical instance models, if we take into account how their internal representations get activated by input from the visual stimulus may consist of three subclasses: logogen models, the lexical search model, and verification models (Carr and Pollatsek, 1985). The logogen models (e.g., Morton, 1979) propose that sensory inputs are fed into a system of stored representations that function as threshold-type detection devices. Each detector responds to sensory inputs as if they were pieces of evidence either for or against the presence of a particular word represented by the detector. If a representation collects enough pieces of evidence to exceed a threshold of certainty that its word is in fact present, then it activates a code or set of codes containing information about the word and makes the information available. To this extent, a reading logogen behaves like the RIGHT track word detector that we discussed earlier. When patterns that look like the word to which it is sensitive appear, its activity level rises. When the activity level rises above a fluctuating threshold value, the logogen (or the RIGHT track detector) signals that it has seen its word. This signal on most occasions is expected to be the actual stimulus word.

Recognition words in this prototype-based model is in general wholistic biased towards more familiar ones, varying with the frequency and recency of their past activations. For a short word of six or fewer letters which are usually high in frequency, the logogen models match it wholistically, but for a longer word, it seems to take into account only the beginning letters of the word. This whole-word visual recognition process does not worry about the inner features of letters or even about letter identification. Its primary data are the outer contour and initial letters. It completes its work of recognition within the first 50-100 msec. after a word is presented.

The logogen models whose lexicons represent words instead of morphemes fail at one point, however: they cannot meet a special requirement to decompose stimulus words that are polymorphemic into their constituent morphemes in recognition process. The Lexical search model (Forster, 1976, 1979; Taft, 1985), in this respect, distinguishes itself from the logogen approach. First, it works through serial matching of sensory input against the members of a list of candidate representations retrieved from the mental lexicon. Second, the candidate list is ordered by frequency of occurrence. In order to avoid establishing the whole lexicon as the search set, an "access code" is postulated which consists of a subset of the letters of the printed stimulus that has to be matched in for a lexical entry to become a candidate in the search. Since the access code may be a subword unit, the model must include processes that can decompose words into these units and map them onto the morphemes represented in the lexicon. The lexical codes, before they make their information available to decision and response mechanisms, are verified by a checking process which checks whether the word chosen in the initial search of the lexicon is in fact the word that is present as the stimulus. If verification fails, then other lexical candidates are tried until the right one is found. More frequently occurring candidates are verified ahead of less frequently occurring candidates.

Using a verification procedure is a characteristic of the lexical search model, but as the mechanisms require to achieve this external confirmation are potentially quite complex and their operation could not account for a considerable portion of the variance in the time course and accuracy of recognition, a third subclass of lexical instance models—the verification models—is developed (see Becker, 1976, 1979). They consist of those that give verification a central place in the recognition process and rely on its properties for a large part of their explanatory power. What seems interesting is that, if we take a closer look at the lexical search model and the verification models, we will find that the combination of these subclasses is functionally similar to part of the LEFT track detectors, which is especially good at dealing with subparts of structure. The processes as a whole are slower than those of the logogen models. The middle letters of words under such an approach, presumably, may only be used after about 100 msec. (Rayner and Posnansky, 1978). If this is correct, we may assume that after the initial shape, the identities of outer letters (50 msec.) and those inner letters (30-50 mesc.) are determined, the letter identities are then used to confirm the earlier word recognition or to make a new attempt. This second letter-based recognition may be complete by 150 msec. (Rayner and Posnansky, 1978).

Standing in contrast to the three types of lexical instance models are the dual-route models. The strong version of the dual-route models, according to Humphreys and Evett (1985), holds that there exists independent lexical and nonlexical routes for processing words. Either of these routes can enable words to be recognized, and the dependence of word recognition on either route will be determined by their relative speed. The lexical processing route is thought to operate by a direct mapping of a word's visual characteristics onto a stored lexical representation. The non-lexical processing route, is thought to process visually unfamiliar words that do not have entries in the visual lexicon, because they have not been read before (e.g., pseudowords). This nonlexical route operates by translating the word's graphemic code into a phonological code on the basis of a small set of abstracted spelling-to-sound rules. In other words, access to phonology in the lexical route is mediated by access to the semantic knowledge store, whereas phonological information is directly accessed from the orthographic lexicon in the nonlexical route. Semantic access of a word is the result of "horse race" between visual and phonological recoding somewhere in the course of semantic processing.

Both lexical instance models and dual-route models as described are functionally appealing. Theoretical and empirical evidence at present seems to favor an expanded, and therefore rather complicated version of the dual-route, rather than the instance lexical models, in terms of its ability to handle data from tachistoscopic recognition, pronunciation, lexical and semantic judgements, and context effects, despite the surprising success of lexical instance models at achieving behavior that appears to be rule-governed in addition to their more expected success with behavior that is specific to a particular stimulus (Carr and Pollatsek, 1985). According to Carr and Pollatsek, the main features of such a modified model in word recognition should contain three parallel systems. Two of these are driven directly by the processing of visual code formation: a visual-orthographic pathway to whole word meaning and a visual-orthographic pathway mediated by morphemic decomposition. The third is a pathway based on phonological recoding, which itself has an internal structure consisting of parallel mechanisms, one working on paired associate of logogen-like principles and one working on grapheme-to-phoneme translation rules.

This expanded version of the dual-route model shares most functions with the three-route approach suggested by Taylor and Taylor (1983) in which they also propose similar routes to word recognition: a direct but approximate visual word recognition; a whole-word recognition based on the identities of the letters in the word; a scan-parse mechanism that works left-to-right and slowly using their letter identities to provide a phonetic transcription of the letter string, whether or not it is a word. The third process also serves to verify the faster work of the other two. The process procedures of the first two routes have been described while discussing the lexical instance models. The third scan-parse process, following Taylor and Taylor, begins when the letters have been recognized and are made available not only to the whole-word recognition but to a scan-parse system that takes them sequentially, left-to-right, for transformation into a phonetic form. The processing begins to produce results by about 150 msec. after the word is presented. The only apparent inadequacy with Taylor and Taylor's approach, is that it does not specify how letters are converted to sounds. It is not clear whether it is through rule-governed knowledge or analogical procedures.

An attempt made in this direction is found in a simple expansion of the dual-route model which Patterson and Morton (1985) called "the dual-routine model". In this model, there are three routines for word recognition, two of these are lexical and one is nonlexical. The central procedure of the nonlexical routine consists of a set of mapping rules from orthographic strings to phonology strings; that is, the orthography-to-phonology correspondence (OPC) system. The OPC system not only maintains an old grapheme-to-phoneme subsystem, but also postulates a new "body" subsystem which allows readers to account for variable pronunciation assignments to ambiguous non-words and augmented pronunciation latencies for both ambiguous words and non-words.

Although the debate over whether it is rule-governed knowledge or analogical procedure that does the work of letter-to-sound conversion is not over, and there are attacks of the dual-route models, it is generally accepted among experts that word recognition in English involves both direct and indirect approaches. While all these models are built for English word recognition, similar psychological involvement should be expected in other orthographies. Besner (1987) in his selective review of evidence from dyslexic, aphasic, dysarthric and intact subjects concludes that while linguistic descriptions of various orthographies are quite different, the psychological operations applied in aid of their recognition appear more similar than previously thought. "Graphemic" and "phonological" codes are involved in lexical access across a number of orthographies despite the nature of the representation underlying these codes appearing quite different in some instances. Similar conclusions are found in Tzeng and Hung (1980), Hung and Tzeng (1981), Seidenberg (1985) who have done most of the experiments with Chinese subjects in this respect.

Evidence of Direct Recognition in Chinese

The idea that Chinese characters are mainly processed on a direct visual route has been taken for granted. The problem with this idea is that not all the characters are processed on a visual basis and that there are some specific requirements underlying this direct recognition. Of them, frequency seems to be an important element since there has been an emerging concensus among researchers that highly familiar words are accessed from visual information with relatively small contributions from morphemic structure, or spelling-to-sound correspondence.

Lexical access involves getting into the right location in memory, activating some kind of long-term memory representation that contains experientially established information about the particular string of letters that is currently available or that was most recently available to the senses (Carr and Pollatsek, 1985). The time course of word recognition depends greatly on word frequency. Experimental studies (Howes and Solomon, 1951, in Segui et al., 1982) have shown that recognition threshold for tachistoscopically presented words is a function of the logarithm of their frequency. Studies in lexical decision and pronunciation (e.g., Rubenstein et al., 1970; Forster and Chambers, 1973) have also found a good correlation between recognition threshold latency and word frequency. So pervasive was this frequency effect that Morton (1969) and Forster (1976) in their models of lexical access emphasize that activation of a word is accomplished on the basis of the frequency occurrence of the stimulus word.

More recently, Seidenberg et al.'s (1984) experiments demonstrate that higher frequency words show greater evidence of direct visual access than lower frequency words. In their experiments of lexical decision and pronunciation, they show that a large pool of words in English are recognized on a visual basis; the extent to which the written forms encoding phonology is irrelevant to the recognition of higher frequency words. To see whether this occurs across orthographies, Seidenberg (1985) conducted an experiment examining word recognition in Chinese. In the experiment, subjects viewed one set of stimuli, which was presented tachistoscopically. There were two sets of stimuli, with 60 characters each, in each set there were four types of characters, a result of crossing the factors type (phonogram and nonphonogram); half of the characters were high in frequency, while the other half were lower in frequency. The results of the experiment are: both sets of stimuli yielded similar results. For higher frequency characters, the mean naming latencies for phonograms and nonphonograms did not reliably differ. For lower frequency characters, however, phonograms were named faster than nonphonograms.

Two things are reflected in the results: (1) while higher frequency characters were named more quickly than lower frequency characters, phonograms were read more quickly than nonphonograms only when the stimuli were low in frequency; (2) high frequency characters were read equally fast, whether they were phonograms or arbitrary; involvement of phonology encoded in the stimuli was limited in lower frequency items. The conclusion that Seidenberg draws, together with another similar experiment on English, is that within each of the two writing systems that differ in the manner in which they represent phonology, a large number of common words are recognized on a visual basis. Recognition of these words is insensitive to phonological information encoded.

Under such an approach on higher frequency, recognition of a word may be initiated with the extraction of visual information from the input. Wholistic access results when sufficient orthographic information is extracted. Access of phonology, an automatic consequence of word recognition, can be regarded as postlexical.

Evidence of Phonological Recoding in Chinese

While Seidenberg's experiment shows that use of phonology is limited to low frequency characters, experiments by Tzeng and Hung (1980), Tzeng et al. (1977) serve as evidence of phonological recoding of visually presented characters. In one of their experiments (1980), the subject was asked to make one of three decisions: (1) graphemic decision, (2) phonetic decision, or (3) sentence judgment in which the subject was asked to determine whether a string of characters formed a meaningful and grammatically correct sentence. For both the graphemic and phonetic decision tasks, a target character was presented above a string of seven or eight different characters and the subject was asked to look at the target character and then scan the string of characters in order to make the appropriate decisions. It was found that there was a tremendous effect on the phonetic decision. The result is consistent with those reported by Tzeng et al. (1977), in which they observed that phonemic similarity of visually presented characters adversely affects short-term retention. Recall was worst for those characters that shared an initial consonant as well as the following vowel and about the same for those that shared either only an initial consonant or only final vowel. Furthermore, the more phonetically similar an interference list was to a target list, the worse the recall of the target list. In judging whether a sentence was grammatical or not, reaction times depended on the degree of phonemic similarity among characters constituting the sentence: they were faster for phonemically variegated sentences, especially for ungrammatical ones, than for phonemically uniform ones.

Chu-Chang and Loritz (1977) demonstrated that written Chinese characters, too, are represented phonetically in short-term memory. They showed, very briefly, 15 isolated characters to Chinese high school students. The characters then had to be recognized among 90 response characters, 15 of which were homonyms, 15 synonyms, 15 shape mates, and 45 correct items. The largest number of errors in recognition was phonetic.

In another experiment (Treiman et al., 1981), American and Chinese subjects silently read two types of sentence: a homophone sentence (e.g., A pair is a fruit.), and a control sentence (e.g., A pier is a fruit.) in their own language, and judged their truth or falsity. Both groups of subjects took longer to respond to the homophone sentences than to the control sentences. But English speakers made more errors, whereas Chinese speakers made fewer errors, on the homophone than on the control sentences. Chinese speakers used phonetic recoding, but to a lesser extent than did English speakers.

Yik (1978) manipulated some single character pairs in acoustic similarity, others in visual similarity effect on memory. The visual effect was particularly pronounced in the absence of acoustic similarity between the characters. In other words, if characters sounded similar, visual dissimilarity had less effect. Evidently, phonological recoding plays an important role in reading Chinese characters. Regardless of the orthographic differences in the initial encoding, the recoding process seems to be governed by the general law of acoustic memory.

Phonological recoding is the process by which internal representation of written symbols is transformed into internal representation of sound symbols, which can be represented by "chains of phonemes" (Gunther, 1987). In English this process may be achieved by rule-governed knowledge (e.g., grapheme-phoneme correspondences)(see Patterson and Morton, 1985), or by analogical knowledge (see Henderson, 1985), whereas in Chinese written words are transformed into spoken forms, presumably by analogy (Tzeng et al., 1986). Although the debate about whether GPC or analogy does the work of conversion in English has generated more heat than light (Kay, 1987). Conversion by analogy in Chinese seems quite appealing: (1) While an English letter has phonetic content and thus can be converted to sound by GPC rules, a stroke in Chinese characters has no phonetic function. Sound conversion can only occur at character level. (2) The fact that phonograms are recognized faster than non-phonograms suggests that the phonetic element in the character is used. This use of the phonetic element implies that some kind of decomposition is carried out, that is, a character may have been decomposed into a signific and a phonetic. Studies show that parts of a stimulus word that happen to be words or morphemes themselves become temporarily activated, even when they are not appropriate subunits of the stimulus (e.g., *bear* as a temporarily activated subunit of *beard*). (see Carr and Pollatsek, 1985). Rubin et al. (1979, in Carr and Pollatsek, 1985) propose that decomposition is an optional strategy that can be adopted when task conditions make it beneficial. Since Chinese characters only hint that an X morpheme should be pronounced like a Y morpheme. Such a representation of sound differs from English in which it indicates that a morpheme should be read as segment 1 followed by segment 2 followed by segment 3 and so on (Wang, 1981), this strategy of hinting sound rather than ascertaining it, apparently, is more like analogy, upon a character being decomposed, because, according to analogy theory, phonology can be assembled by 1) finding words that contain the appropriate orthographic segments; 2) obtaining the phonology corresponding to those segments; 3), cobbling together a pronunciation. (3) Normal readers have available a word-specific procedure for converting print to sound without any influence from sub-word components (Coltheart and Funnell, 1987), thus low frequency nonphonograms as well as higher frequency characters, presumably, may undergo a whole-word translation procedure, mapping themselves to the specific pronunciation in the lexicon. Such a way of mapping is in fact by analogy (see Baron, 1976, 1977).

Multi-character Word Processing: A Combination

A written Chinese word may consist of a single character or of two or more separate characters for communicating a meaning. A character in such a circumstance is very much like an English morpheme except that a character itself is uniformly arranged with a space after each character. As there is a large number of homophones in Chinese, single characters are combined to form a multi-character word as a means of minimizing ambiguity. One common way of such formation is by repeating a synonymous character or even the same character, as in 看见 "look see" for "see", 房屋 "house buildiing" for "house", and 弟弟 "brother brother" for 'younger brother". While there are other ways of forming, the meaning of a multi-character word in general can be inferred from the meaning of its constituent characters. For example, the meaning of "psychology" is represented by three characters 心 "mind" 理 "logic" and 学 "study". The same is "library: 图 "picture" 书 "book" 馆 "building".

To process a multi-character word in Chinese, therefore, is similar to processing morpheme by morpheme. As each morpheme is separated by a space in Chinese, the reader has to know how to segment a sequence of separate characters into a meaningful word sequence. This task requires a series of multi-leveled visual, hemispheric and cognitive operations as described below:

Comprehension deals with the sequential nature of language by trying to interpret each successive morpheme of a text as soon as they are encountered (Just and Carpenter, 1987). When the first character of a multi-character word is fixated, all levels of comprehension begins, which include encoding the word, accessing its meaning, associating it with referent, and determining its semantic and syntactic status in the discourse (Just and Carpenter, 1987). This stage of recognition may have two outputs: (1) a phonological representation used for further analysis of how the character fits with other characters, and (2) a semantic representation used to determine how the character fits into the real word context. Since the RIGHT and LEFT work together, the syntactic function of the morpheme is transmitted to the LEFT track, its content to the RIGHT (Taylor and Taylor, 1983). When enough information about the character is processed, the information is put into the working memory while the other character is being processed. Phonology, which can facilitate the working memory processes, is coded to preserve and retain information concerning the literal sequential character. After the second or third character is identified and its meaning is activated, associations between the characters may occur. If, however, the second character has more than one meaning, the most frequent one is assumed to first reach threshold, and a word may be claimed to be recognized. This claim made by the RIGHT track detector based on the visual features detectors will not give rise to any problem if it fits the context, that is, it matches the meaning of the proceding character(s). If the meaning does not fit the context, which presumably is the result of being checked by the LEFT track, the LEFT track will cancel the RIGHT track candidate, and the whole system may be reset until it fits.

There are two reasons to support this assumption. First, studies have found that readers can realize at some level that a word has been misinterpreted, and that they are relatively efficient in recovering (Taylor and Taylor, 1983; Just and Carpenter, 1987). Second, Taft (1985) shows that semantic priming of the second morpheme depends largely on the first morpheme. He claims that the primary access code in recognizing compound words (e.g., seaweed) is the first item *sea*, the second item *weed* only plays a secondary access route.

While characters of a compound word are processed and associated from bottom up, interpretation of their meanings must be in a top down fashion, governed by high order syntactic organization. For example, in the process of interpreting 图书馆 "library", which consists of "picture book building", the reader, based on priming and associating (RIGHT track work), will take the innermost noun "building" as the head, and the next innermost noun "book" as a modifier forming a unit "book building", meaning "publishing house"(LEFT track work). This unit when it is further modified by the next noun "picture" changes its meaning to "library" since the combination of "picture book" as a whole is more common and more frequent than "book building"; moreover, "picture book library" can be a concept itself (LEFT track work). These interactions are unconscious of course, but they are part of the complicated process in syntactic parsing.

Another thing about multi-character compound word processing is that when a compound word is high in frequency and contains no more than three characters, it is possible that it is accessed as a whole. But if the compound word is lower in frequency than the constituent character, decomposition may result (see Just and Carpenter, 1987). This is reasonable if we take into account that each character has the same size and that a fixation at a time can cover 2.5 characters.

Summary

Word recognition is by no means a simple process. It requires the analysis of a certain amount of visual features acquired while the word is fixated. Visual features refer not only to distinctive features of single letters/strokes, but also to word/character shape and printing conventions. Extraction of these features are carried out by the RIGHT track and the LEFT track. The LEFT track can process all kinds of words, characters and stroke clusters, whereas the RIGHT track prefers to process familiar words. The RIGHT track uses a global process to produce a set of reasonable possibilities for recognition and the LEFT track works on these possibilities, using an analytic process to guide analysis. They operate in parallel. If the stimulus is a familiar word, it is recognized mainly by its shape and outer contour, the set of features is compared to property lists or pattern description in memory. If the stimulus is familiar but visually complicated, some sort of decomposition is done. Operation in this routine is always fast and global. When the stimulus is less familiar, an indirect phonological route is employed, and recognition is operated at a slower rate.

In short, a pathway based on whole words may work in parallel with a pathway based on morphemic decomposition. In either pathway or route, encoding of the visual information necessary for reading occurs during the first 50 mesc. of a fixation. The remainder of the fixation is for carrying out processes associated with lexical access, syntactic parsing and perhaps higher level semantic integration.

CHAPTER 4

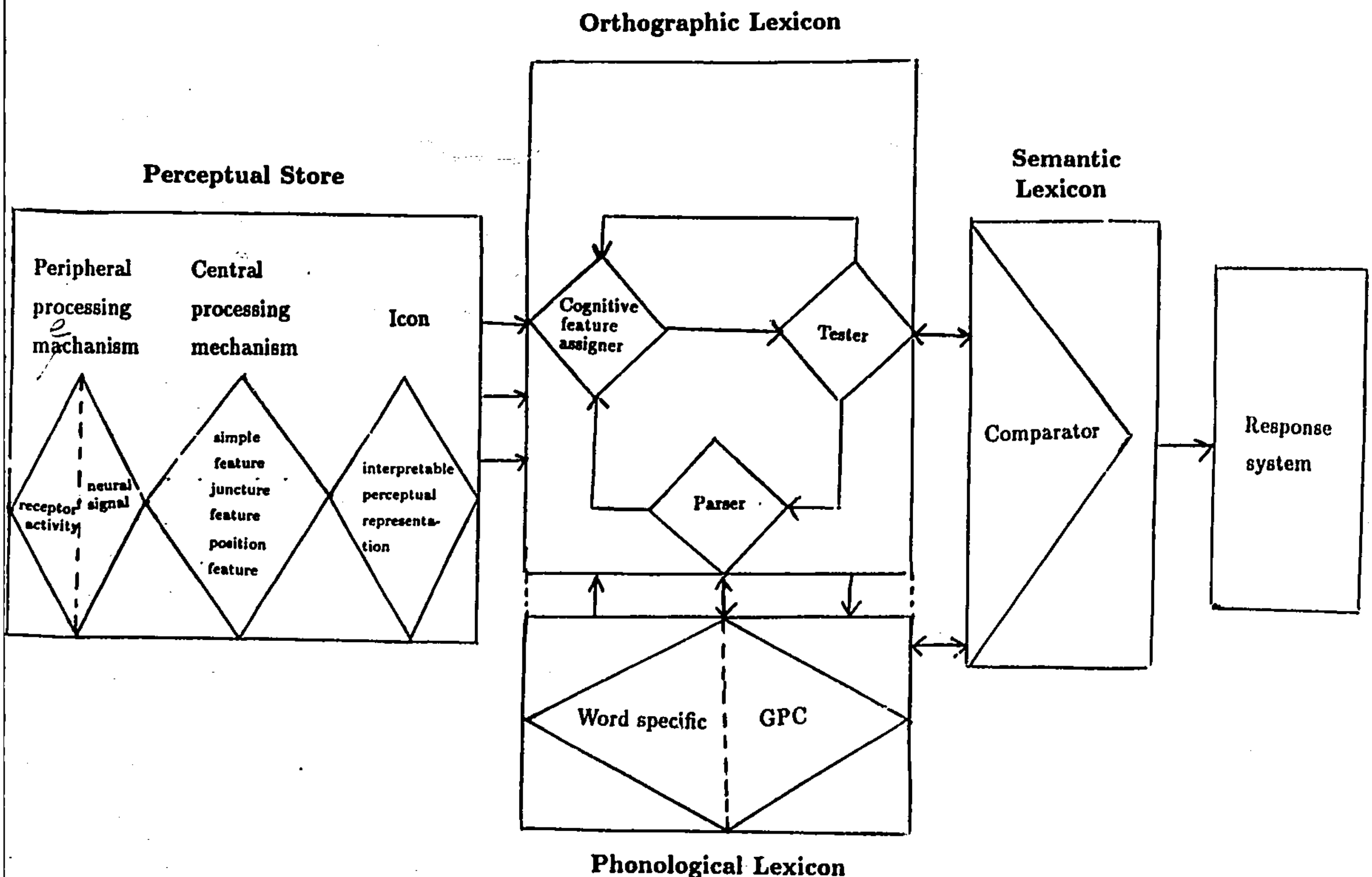
Toward a Model of Written Word Recognition in Chinese

Reading a word for meaning consists of extracting some form of information from signs and using this information to reach the word's entry in the lexicon. The whole processes of word recognition can be divided into visual encoding, lexical access and recognition. There have been various models proposed in an attempt to cover these processes, but the focus of these models has been very different. Some concentrate on visual perception (e.g., Johnson, 1977, 1981), some on lexical access (Morton, 1969; Patterson and Morton, 1980; Morton and Patterson, 1985; Forster, 1976; Coltheart et al., 1977), while others stick to recognition as a whole (e.g., Seidenberg, 1985b). There seems no model providing a detailed description starting from the very onset of initial perceptual encoding up to the stage where a word is recognized in terms of single word recognition. Constructing a model in terms of Chinese character processing provides an opportunity to bridge this gap.

Outline of the Model

Information processing of human memory can be classified as three major structural components: the sensory register, the short-term memory, and the long-term memory (Shiffrin and Atkinson, 1969). The sensory register is a non-cognitive system, while both the short-term memory and the long-term memory are cognitive systems (Johnson, 1981). Somewhere around or within the cognitive systems is the mental lexicon, a mechanism specifically responsible for word recognition. It consists of an orthographic lexicon, a phonological lexicon, and a semantic lexicon. As our model is to explain how information of a visual word is processed from print to meaning, its basic structure is made up of four components: a perceptual store, an orthographic lexicon, a phonological lexicon, and a semantic lexicon. These four components together with their mechanisms are depicted in Figure 5:

Fig. 5 Components of the Model



The perceptual store can be viewed as an interface between a biological system that is sensitive to energy changes in the environment and a cognitive system in which the information can be transformed to accomplish some presented task (Johnson, 1977). It is free of attentional demand and not subject to cognitive intervention (Johnson, 1977). There are three mechanisms in the perceptual store: the peripheral processing mechanism, the central processing mechanism and the icon. The main function of peripheral processing mechanism is to relay the signal from some type of receptors to the central processing mechanism. The signal relayed is undifferentiated when it reaches the central processing merchanism.

The central processing mechanism is responsible for detecting all the potential features within an array which include simple features (e.g., horizontal, vertical and diagonal lines and curves); juncture features (i.e., features representing intersections and points of contact between simple features) whose encoding act as a mechanism fusing the simple features into a higher-order feature assemblage; position features which represent the spatial relationships within an array. The result of this encoding and detecting is that features within the signal becomes increasingly differentiated.

The icon is a visual system with the features of the iconic representation being encodings of physical attributes of the exposed word (Johnson, 1977). It is assumed that the end product of feature detection and encoding is an interpretable perceptual representation which can be encoded into a form compatible with subsequent cognitive processing.

The orthographic lexicon is part of a recognition device responsible for visually presented words. It contains information about the orthorgraphic properties of a word and its function is to prepare a coded description of the target word for recognition (Forster, 1976). Perceptual-to-lexical match that is necessary for lexical access to occur is supposed to take place in this lexicon (Taft, 1985, Forster, 1976). Words in the orthographic lexicon are listed in order of their frequency in the language; the access code of a word can be a full word, a stem morpheme, and so on (Taft, 1985).

The orthographic lexion is composed of three basic parts: the cognitive-feature assigner, the frequency tester and the parser (see Johnson, 1977). The function of the feature assigner is to accept perceptually encoded information and assign to it a set of cognitive features that can be used for subsequent processing. It is a mechanism that allows for a contact between perception and memory. The perceptual input to the feature assigner could be from the icon or from the tester-parser (Johnson, 1977, 1981). The function of the tester-parser is to determine if an encoding generated by the feature assigner is adequate for lexical access. If an encoding is found to be high in frequency by the tester, it is passed on and registered in the semantic lexicon. If the encoding is low in frequency, it is transferred to the parser where the parser finds a way to decompose the encoding into components in order that they are readily accessable. Phonological activation is assumed to take place at this moment.

The phonological lexicon contains units that are related to acoustic and articulatory inputs. The units represented in it include distinctive features, phonemes, syllables, morphemes and even full words (Samuels and Kaml, 1984). Its function include supporting visual perception, getting word's meaning and holding words in the short-term memory (Taylor and Taylor, 1983; Seidenberg, 1985b).

There are presumably two mechanisms in the phonological lexicon: a GPC mechanism (Coltheart et al, 1977; Patterson and Morton, 1985), and a word-specific mechanism (Baron, 1977, Baron and Strawson, 1976). The GPC mechanism is the most favored candidate for a system of sublexic phonological recoding (see Patterson and Morton, 1985). According to this mechanism, written letter strings are segmented into graphemes which are then assigned phonemic correspondences by rule. Pronunciation is then assembled with the aid of coarticulation rules (Morton and Patterson, 1980). The word specific mechanism, which is proposed by Baron and Strawson (1976) and supported by Glushko (1979) and Kay (1987), relies on specific knowledge of pronunciations of particular words or morphemes. According to Baron (1977), the existence of word-specific mechanism is suggested by our ability to pronounce words that are exceptions to rules (e.g., lb., Ag.); such an ability to access whole word pronunciations can only be accounted for by analogy, a conscious strategy of recalling a similar word and then modifying its pronunciation. Glushko (1979) further modified it by suggesting that lexical access for real words is activated on a wholistic basis.

While the GPC mechanism is challenged by Kay (1987) and the analogy theory is challenged by Patterson and Morton (1985), there is one thing which is certain in terms of processing Chinese characters: a stroke or a stroke cluster in Chinese has no phonetic content, a GPC rule which states that a medial vowel is pronounced as short unless it procedes a consonant followed by a final *e* (e.g., fin, fine or flat and flate) simply does not apply in Chinese. The theory of analogy is appealing to Chinese because the way reading aloud by analogy in English is very similar to what readers of Chinese do in actual reading, particularly, in guessing an unknown word. For example, when encountering a pseudoword, say, VATE in English, readers seem to use the multi-letter correspondence of the familiar -ATE pattern and prononce it /vet/ by analogy with a word like GATE. In other words, readers use larger and more specific units of orthographic and phonological structure (Glushko, 1979). By the same token, Chinese readers, when encountering an unknown word (e.g., 𫓶), tend to strip off the radical 钅 and read it as /ma/ by analogy with a word like 码, because 马 is a very common phonetic. Ohala (1974, in Glushko, 1979) suggests that using analogy with existing words need not always be correct, Taft (1985) also shows that prefixed words seem to be recognized after the prefix is stripped off. Given these similarities, it seems reasonable to assume that pronouncing a word in Chinese is generated by analogy.

The semantic lexicon stores lexical information about words. Its function is to check back to the encoded representations of the presented word in order to confirm that the correct entry has been accessed (Taft, 1985). Concepts represented in this lexicon resemble an intricate spider-web, with strands linking one another among them. When an access code comes in from the orthographic or phonological lexicon, it is matched with the knowledge stored in the semantic lexicon. To the extent that there is a good match between the access code and the stored concepts, a word is recognized (Samuels and Kaml, 1984; Aitchison, 1987).

An important mechanism in the semantic lexicon is the comparator. Regardless of whether the task is to read or pronounce a word, some kind of comparison processes is involved. The result of the comparison (e.g., same or different) can be relayed to the response system, if it is required (Johnson, 1977, 1981).

Accessing the Chinese Mental Lexicon

There are several stages which are of particular importance when a visual stimulus is on its journey from display to meaninig: the stage where visual features are unitized into a visual percept; the stage where phonology intervenes; the stage where high/low frequency words are accessed; and lastly the stage where a pseudoword is processed. The model described below is very explicit when approaching these stages.

To begin, when a printed visual word (e.g., 山) is displayed and fixated, perceptual processing initiates with some type of receptor activity in the retina which is then immediately recoded into a neural signal. The neural signal is transmitted through the peripheral system via the optic path ways to the central processing mechanism. Simple features such as length or width of curves and lines of different orientations (e.g., here 山 has three vertical lines and one horizontal line; the vertical lines are wider but shorter than the horizontal line) are detected; at the same time, juncture features which are detected (e.g., there are three juncture features in 山 that represent the intersections of the four simple features) act as a mechanism for fusing the simple features into a higher-order iconic assemblage such that it can be represented by a single iconic encoding. In addition, the detected positional information (e.g., relation, arrangement, blank space) governs that the particular feature assemblage should be positioned in a way that its opening is northward (e.g., 山) instead of southward (e.g., 冚). While features are interpretable and independent at this stage, it is assumed (Johnson, 1981) that features themselves will no longer be available for processing once feature extraction ends and the iconic representation is established, and that it is the overall perceptual pattern that is immediately available to cognitive processing.

When the overall perceptual representation is established, it is transformed to cognitive processing mechanisms. In the process during which it is transformed into the orthographic lexicon, it receives cognitive features from the feature assigner (Johnson, 1981), and excites whole-word detectors in the orthographic lexicon (Taylor and Taylor, 1983). The exciting of the whole word detectors activates the input pattern that is represented as a set of integrated features assemblage within the perceptual system (Rumelhart, 1971). The activation of the overalll perceptual pattern excites all the features embedded or fused in the higher-order assemblage, resulting in an integration of the features from outward in through mutual inhabition and by feedback from high levels (Taylor and Taylor, 1983). The reader's knowledge about orthographic structure (Massaro, 1980) together with the utilization of these information in perceptual storage leads to the unitization of all the features. With the completion of cognitive recoding, a concrete, synthesized visual image occurs.

The process described up to this stage is analogous to photo developing where nothing appears on the photograph paper after sensitization, but everything comes up as soon as it is filtrated in the liquid developer. The processes up to the icon resembles sensitizations, while the process of cognitive recoding resembles developing. It is only after the developing process can we say that one really "sees" the word. The whole processes, thus, proceed from vagueness to clearness, and they are ready to become vagueness again.

With this perceptual registration in the cognitive mechanisms, the tester starts to encode the visual word percept as an abstract representation of its physical properties and then compares it to a memory representation (Reed, 1973). If the visual percept is found to be familiar and common, it is passed on and registered in the semantic lexicon, where a detailed comparison between the properties of the access code, which is a full word, and the properties of the input previously stored in the semantic lexicon is made. At some point where there is enough similarity between them, and where the activation level throughout the network passes a threshold amount, the word is recognized. Conceivably, simple and unique words are tested and matched fast, whereas complex words and words with many exemplars (e.g., [illegible] , [illegible], and [illegible]) may require some classification in testing and matching; that is some decomposition may be done. But recognition as a whole is direct and fast. Phonological representations about the word are automatically activated following recognition. "A pronunciation is generated using procedures for determining how to modify the activated information in order to synthesize the desired articulary program." (Glushko, 1979).

However, when the visual percept is tested to be less familiar (e.g., [illegible] or [illegible]), it is transferred to the parser where it is decomposed into components. A problem immediately arise is that the amount of time in which the short-term memory can store information without rehearsal is very limited (Samuels and Kaml, 1984). To prevent the visual percept from decaying before the information is transferred to the semantic lexicon, there must be some means to facilitate the short-term memory so that it can maintain the perceptual representation (Johnson, 1977). Phonological information is presumably activated here. Given that this is the case, we may assume that, as soon as the character is segmented, it is recoded by the word-specific mechanism and passed on to the semantic lexicon, provided that the orthographic lexicon and the semantic lexicon are interconnected by excitatory links. Characters composed of elements (e.g., [illegible] here) may be segmented faster than characters which are nuclear themselves (e.g., [illegible]), given the characteristic of the parser; phonograms may be recoded faster than nonphonograms, since a phonogram hints sound. In the semantic lexicon, the properties of the phonological code are compared with the properties of the input that have been previously located. In addition, A spelling check may be carried out in case there is a homophone. When everything is matched, activation reaches threshold, and the word is recognized.

In case the visual percept is a pseudoword, there will be an exhaustive search, both visually and phonologically. The tester transfers it to the parser after its low frequency is determined, and the parser, upon segmenting it into components, signals them serially back to the feature assigner for another try. If it is a pseudophonogram, it is recoded to some type of phonological representation by analogy, and passed on to the semantic lexicon for examination, where it fails at spelling check. If it is a pseudononphonogram, it is mainly searched through the orthographic lexicon. In both cases, the semantic lexicon is highly activated, but not to the threshold level.

This series of processes — perception, lexical access, and recognition in recognizing a displayed word — to give an analogy, is like an oncoming airplane being detected by a radar system and being shown on a screen as depicted in Figure 1.

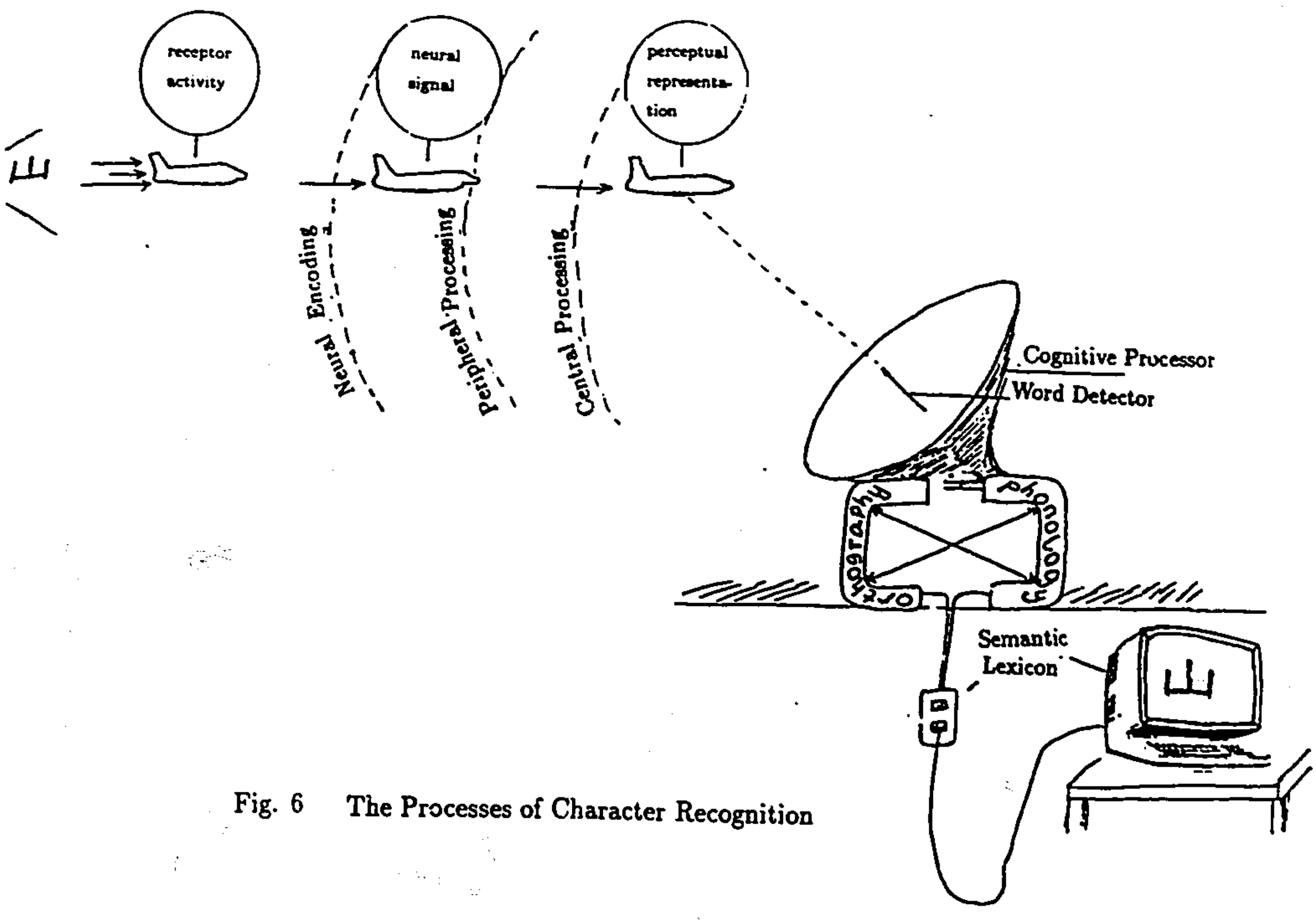


Fig. 6 The Processes of Character Recognition

CHAPTER 5

Summary and Conclusion

Every Chinese character has a shape, a sound and a meaning; processing Chinese characters involves visual encoding, phonological recoding and semantic accessing. Chinese characters are not picture-like in the sense of iconicity; rather, they are linguistic symbols. Phonological information is represented in the characters and it provides a good guide to most characters despite diachronic processes. In comparison to significs, phonological components are superior, for they are more useful in predicting pronuncication than significs are in predicting meaning. Given that Chinese characters represent morphemes, and they represent them phonologically for the most part, and that each character is pronounced as a syllable and the pronunciation of the character can be obtained through the intermediary of the phonetic, the Chinese writing should be best considered as "morphosyllabic".

Reading Chinese characters and reading English words share similar processes in general, although there are some low-level differences such as: the square shape of the characters and their compact arrangement in a line demand frequent eye movements; visual density invites stronger involvement in reading Chinese than in English. Both factors suggest that visual processing plays a more distinctive role in remembering and processing Chinese characters. An immediate effect of this distinction in character processing is that the right hemisphere is more active than the left hemisphere in the first 50 msec. of a fixation. But in the whole process of character recognition, the left hemisphere is more important; recognition of a Chinese character in fact involves both the hemispheres. Like English, a large number of Chinese characters are recognized on a visual basis, only those characters low in frequency are recognized phonologically through word spcefic analogy.

In the model constructed, it is assumed that perceptual processing initiates with some type of receptor activity in the retina which is then immediately recoded into a neural signal. The neural signal is transmitted through the peripheral system via the optic pathways to the central processing mechanism where features of various kinds are extracted. Once feature extraction is completed, an iconic representation is established, ready for cognitive processing. The result of cognitive processing is a concrete, synthesized visual image. If the visual image of the word is tested to be familiar, it is passed on to the semantic lexicon where comparison is made. When there is enough similarity occuring, the word is recognized. If the visual image is tested to be less familiar, phonological recoding is invited and the word is decomposed. The word is recognized when everything is matched in the semantic lexicon. If, however, the visual image is found to be a pseudoword, there will be an exhaustive search, both phonologically and visually. In either case, the semantic lexicon is highly activated, but not to the threshold level.

Given that this thesis is a comprehensive review and synthesis of current literature on Chinese characters in terms of linguistic and cognitive perspectives, and that the model provided is purely on a theoretical basis, with the purpose of providing a detailed description of word recognition in Chinese, empirical evidence is very much needed to test what has been proposed here. It is believed that with more and more empirical data, the model may become fuller and clearer. Further research on character recognition may first focus on such questions as: (1) How long does it take to encode familiar and simple characters? Is it exactly the same as those in English which occurs in the first 50 msec. of a fixation, or longer? (2) Given that a character is high in frequency, is there any latency difference if it is written in a complex version as opposed to simple version? This question is interesting and important, because Just and Carpenter (1987) conclude that Chinese characters are encoded stroke(s) by stroke(s) after observing that the amount of time that Chinese readers spent on each character increased linearly with the number of strokes. (3) Does decomposition occur if a character is high in frequency but complex in visual aspect? This question is relative to (2) in that if there is a difference in (2), the answer is positive, or vise versa. In short, cognitive study of Chinese characters is still at its early stage, more things are waiting to be done if we want to have a clear understanding of the nature of language processing.

References

Ai, J. W. (1950). "A Report on Psychological Studies of the Chinese Language in the Past Three Decades". **The Journal of Genetic Psychology**, 76, 207-220.

——- (1955). **The Psychology of Reading: The Question of Chinese Characters.** Taiwan: Chunghua. (in Chinese).

Aitchison, J. (1987). **Words in the Mind: An Introduction to the Mental Lexicon.** Oxford: Basil blankwell Ltd.. UK.

Allport, D. A. (1977). "On Knowing the Meaning of Words We Are Unable to Report: The Effect of Visual Masking". **Attention and Performance**, VI, 505-534.

Baron, J. (1977). "Mechanisms for Pronouncing Printed Words: Use and Acquisition". in D. LaBerge and S. Samuels (Eds.). **basic Processes in Reading: Perception and Comprehension.** 175-216. Hillsdale, N.J.: Erlbaum.

Baron, J. and Strawson, C. (1976). "Use of Orthographic and Word-specific Knowledge in Reading Words Aloud". **Journal of Experimental Psychology: Human Perception and Performance**, 3, 386-393.

Barron, R. W. (1981). "Development of Visual Word Recognition: A Review". **Reading Research: Advances in Theory and Practice**, 3, 119-151.

Becker, C. A. (1976). "Allocation of Attention during Visual Word Recognition". **Journal of Experimental Psychology: Human Perception and Performance**, 2, 556-566.

————(1979). "Semantic Context and Word Frequency Effects in Visual Word Recognition". **Journal of Experimental Psychology: Human Perception and Performce**, 5, 252, 259.

Besner, D. and Coltheart, M. (1979). "Ideographic and Alphabetic Processing in Skilled Reading of English". **Neuropsychologia**, 17, 467-472.

Besner, D.; Daniels, S.; and Slade, C.. (1982). "Ideographs Reading and Right Hemisphere language". **British Journal of Psychology**, 73, 21-28.

Besner, D. (1987). "On the Relationship between Orthographies and Phonologies in Visual Word Recognition". in A. Allport; D. Mackay; W. Prinz; E. Scheerer (Eds.). **Language Perception and Production: Relationships between Listening, Speaking, Reading and Writing.** 211-226. London: Academic Press.

Borsodi, R. (1967). **The Definition of Definition.** Massachusetts: Porter Sargent Publisher.

Briederman, I. and Tsao, Y-C. (1979). "On Processing Chinese Ideographs and English Words: Some Implications from Stroop Test Results". **Cognitive Psychology**, 11, 125-132.

Bub, A.; Cancelliere, A.; Kertesz, A. (1985). "Whole-Word and Analitic Translation of Spelling to Sound in a Non-semantic Reader". in K. E. Patterson; J.C. Marshall; and M. Coltheart (Eds.). **Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Recoding.** 15-34. New Jersey: Lawrence Erlbaum Associates, Publishers.

Butterworth, B. (1980). "Lexical Representation". in B. Butterworth (Ed.). **Language Production. Vol. 2. Development, Writing and Other Processes.** 257-290. London: Academic Press Inc. London Ltd..

Caplan, D. C. (1987). **Neurolinguistics and Linguistic Aphasiology: An Introduction.** Cambridge: Cambridge University Press.

Carr, T. H. and Pollatsek, A. (1985). "Recognizing Printed Words: A Look at Current Models". **Reading Research: Advances in Theory and Practice**, 5, 1-81.

Carrol, J. B. (1972). "The Case for Ideographic Writing". in J. F. Kavanach and I. G. Mattingly (Eds.). **Language by Ear and By Eye.** 103-110. The MIT Press.

Chao, Y. R. (1968). **Language and Symbolic Systems.** Cambridge University Press.

Chen, M. (1971). "Time Variable in Phonological Change". **Journal of Linguistics**, 7, 1-14.

Chen, M. (1972). "The Time Dimension: Contribution toward a Theory of Sound Change". **Foundation of Language**, 8, 457-494.

Chen, M. (1976). "From Middle Chinese to Modern Peking". **Journal of Chinese Linguistics**, 4, 113-277.

Chen, M. and Newman, J. (1984). "From Middle Chinese to Modern Cantonese". **Journal of Chinese Linguistics**, 12, 148-198.

Chen, M. and Wang, W. (1975). "Sound Change: Actuation and Implementation". **Language**, 51,255-281.

Cheng, C-C (1977). "In Defense of Teaching Simplified Characters". **Journal of Chinese Linguistics**, 5, 314-341.

Cheng, C.-M.and Yang, M.-T. (1989). "Lateralization in the Visual Perception of Chinese Characters and Words". **Brain and Language**, 36, 669-689.

Chu-Chang, M. and Loritz, D. J. (1977). "Phonological Encoding of Chinese Ideograms in Short-term Memory". **Language Learning**, 27, 344-352.

Clark, E. V. (1978). "Discovering What Words Can Do". in D. Farkas; W. M. Jacobsen; K. W. Todrys (Eds.). **Papers from the Parasession on the Lexicon.** 34-57. University of Chicago.

Coleman, L. and Kay, P. (1981). "Prototype Semantics: the English Word 'lie'". **Language**, 57, 26-44.

Coltheart, M.; Davelaar, E.; Jonasson, J. T., Budmut. F. (1977). "Access to the Internal Lexicon". in S. Dornic (Ed.). **Attention and Performance**, VI, 535-555.

Coltheart, M. and Funnell, E. (1987). "Reading and Writing: One Lexicon or Two". in A. Allport; D. Mackay; W. Prinz; E. Scheerer (Eds.). **Language Perception**

and Production: Relationship between Listening Speaking, Reading, and Writing. 313-339. London: Academic Press.

DeFrancis, J. (1984). **The Chinese Language: Fact and Fantasy.** Honolulu: University of Hawaii Press.

Downing, J. and Leong, C. K. (1983). **Psychology of Reading.** New York: Macmillan Publishing Co., Inc..

Emmorey, K. D. and Fromkin, V. A. (1988). "The Mental Lexicon". in F. J. Newmeyer (Ed.). **The Cambridge Survey. Vol. III. Language: Psycholinguistics and Biological Aspects.** 123-149. Cambridge: Cambridge University Press.

Fodor, J. D.; Fodor, J. A.; Garrett, M. F. (1975). "The Psychological Unreality of Semantic Representation". **Linguistic Inquiry**, 4, 515-531.

Fodor, J. A. (1983). **Modularity of Mind.** Cambridge: M.A. MIT Press.

Fodor, J. D. (1977). **Semantics: Theories of Meaning in Generative Grammar.** Massachusets: Harvard University Press.

Fok, A. and Bellugi, U. (1986). "The Acquisition of Visual Spatial Script". in H. S. R. Kao; G. P. van Galen; R. Hoosain (Eds.). **Graphonomics: Contemporary Research in Handwriting.** 329-355.

Forster, K. I. (1976). "Accessing the Mental Lexicon". in R. J. Wales and E. Walker (Eds.). **New Approaches to Language Mechanisms: a Collection of Psycholinguistics Studies.** 257-288. Amsterdam: North-Holland Publishing Company. The Netherlands.

——— (1979). "Levels of Processing and the Structure of the Language Processor". in W. E. Cooper and E. C. Walker (Eds.). **Sentence Processing: Psycholinguistics Studies Presented to Merrill Garrett.** 27-85. New Jersey: Lawrence Erlbaum Associates Publishers.

Forster, K. I. and Chambers, S. (1973). "Lexical Access and Naming Time". **Journal of Verbal Learning and Verbal Behavior**, 12, 627-635.

Frauenfelder, U. H. and Tyler, L. K. (Eds.). (1987). **Spoken Word Recognition**. Cambridge: MIT Press.

French, M. A. (1976). "Observations on the Chinese Script and the Classification of Writing Systems". in W. Haas (Ed.). **Writing without Letters**. Rowman and Littlefield: Manchester University Press.

Fromkin, V. (1985). "Evidence in Linguistics". in R. H. Robbins and V. A. Fromkin (Eds.). **Linguistics and Linguistic Evidence**. Newcastle upon Tyne: Grevatt and Grevatt.

Garnham, A. (1985). **Psycholinguistics: Central Topics**. London: Methuen.

Giovanni, B. F. (1988). "Language Perception". in F. J. Newmeyer (Ed). **The Cambridge Survey....** 97-123.

Gleitman, L. R.; Gleitman, H.; Landan, B.; Wanner, E. (1988). "Where Learning Begins: Initial Representation for Language Learning". in F. J. Newmeyer (Ed.). **The Cambridge Survey ....** 150-193.

Glushko, R. J. (1979). "The Organization and Activation of Orthographic Knowledge in Reading Aloud". **Journal of Experimental Psychology: Human Perception and Performance**, 5, 674-691.

Gunther, H. (1987). "Phonological Recoding in the Reading Process". in P. A. Luelsdorff (Ed.). **Orthography and Phonology**. 151-170. Philadelphia: John Benamins Publishig Company.

Guo, M. R. (1951). "Smooth the Road for the Basic Reform". in P. J. Seybolt, and G. K-K. Chiang (Eds.). (1979). **Language Reform in China: Documents and Commentary**. 45-50. Dawson: M. E. Sharpe Inc.

Haber, L. R. and Harber, R. N. (1981). Perceptual Processes in Reading: An Analysis-by-Synthesis Model". **Reading Research: Advances in Theory and Practice**, 3, 167-200.

Hardyck, C.; Tzeng, O. J. L. and Wang, W. S-Y. (1977). "Cerebral Lateralization Effects in Visual Half Experiments". **Nature**, 269, 705-707.

———— (1978). "Cerebral Lateralization of Function and Bilingual Decision Processes: Is Thinking Lateralized?" **Brain and Language**, 5, 56-71.

Hasuike, R.; Tzeng, O.; Hung, D. (1986). "Scripts Effects and Cerebral Lateralization: The Case of Chinese Characters". in J. Vaid (Ed.). **Language Processing in Bilinguals: Psycholinguistic and Neuropsychlogical Perspectives**. 275-288. New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.

Hatta, T. (1977). "Lateral Recognition of Abstract and Concrete Kanji in Japanese". **Perceptual and Motor Skills**, 42, 163-166.

———-(1977a). "Recognition of Japanese Kanji in the Left and Right Visual Fields". **Neuropsychologia**, 15, 685-688.

———-(1980). "Kanji Processing Levels and Cerebral Hemisphere Differences". **Annals of Osuka University of Education IV**, 29, 7-14.

Healy, A. E. (1981). "The Effects of Visual Similarity on Proofreading for Misspellings", **Memory and Cognition**, 9, 453-460.

Henderson, L. (1980). "Wholistic Models of Feature Analysis in Word Recognition: a Critical Examination". in P. A. Kolers; M. E. Kolers; M.E. Wrolstad and B. Herman (Eds.). **In Processing of Visible Language**. 2, 207-218. New York: Plenum Press.

———— (1982). **Orthography and Word Recognition in Reading**. New York: Oxford University Press.

——— (ed.). (1984). **Orthographies and Reading: Perspectives from Cognitive Psychology, Neuropsychology and Linguistics.** London: Erlbaum.

——— (1985). "Issues in the Modelling of Pronunciation Assembly in Normal Reading". in K. E. Patterson; J. C. Marshall and M. Coltheart (Eds.). **Surface Deslexia.** 459-508. New Jersey: Lawrence Erlbaum Associates, Publishers.

Humphreys, G. W. and Evett, L. J. (1985). "Are There Independent Lexical and Nonlexical Routes in Word Processing: An Evaluation of the Dual-route Theory of Reading". **The Behavioral and Brain Sciences**, 8, 689-704.

Huang, S. F. (1987). "Two Studies on Prototype Semantics: Xiao 'Filial Piety' and Mei Mianzi 'Loss of Face'". **Journal of Chinese Linguistics**, 15, 55-89.

Hung, D. L. and Tzeng, O. J. L. (1981). "Orthographic Variations and Visual Information Processing". **Psychological Bulletin**, 90, 377-414.

Johnson, N. F. (1977). "A Pattern-Unit Model of Word Identification". in D. Laberge and S. J. Samuels (Eds). **Basic Processes in Reading: Perception and Comprehension.** 91-126. New Jersey: Lawrence Erlbauml Associates, Publishers.

Johnson, N. F. (1981). "Integration Processes in Word Recognition". in O. J. L. Tzeng and H. Singer (Eds.). **Perception of Print: Reading Research in Experimental Psychology.** 29-64. New Jersey: Lawrence Embaum Associates Publishers.

Just, M. A. and Cartenter, P. A. (1987). **The Psychology of Reading and Language Comprehension.** Massachusetts: Allyn and Bacon, Inc..

Karlgren, B. (1962). **Sound and Symbol in Chinese.** Hong Kong University Press.

Kay, J. (1987). "Phonological Codes in Reading: Assignment of Sub-word Phonology". in A. Allport; D. Mackay; W. Prinz; E. Scheerer (Eds.). **Language Perception and Production: Relationships between Listening, Speaking, Reading and Writing.** 181-196. London: Academic Press.

Keren, G. and Baggen, S. (1981). "Recognition Models of Alphanumeric Characters". **Perception and Psychophysics**, 29, 234-246.

Kintsch, W.(1974). **The Representation of Meaning in Memory**. New Jersey: Lawrence Erlbaum Associates, Inc..

Keung, H. S. and Hoosain, R. (1989). "Right Hemisphere Advantage in Lexical Decision with Two Character Chinese Words". **Brain and Language**, 37, 606-615.

Lacharite, D. P. (1989). "The Right Hemisphere and Processing Components in Reading: Conceptual Clarification Toward a Model". (Unpublished paper. Department of Linguistics, University of Ottawa).

Leong, C. K. (1973). in J. Downing (Ed.). **Comparative Reading: Cross National Studies of Behavior and Processes in Reading and Writing**. 384-402. New York: The Macmillan Company.

Li, X. J. (1958). "Why Chinese Writing did not Become Phonetic Long Ago?". in P. J. Seybolt and G. K-K. Chiang (Eds.). (1979). **Language Reform in China: Documents and Commentary**. 244-253. Dawson: M .E. Sharpe Inc.

Lotz, J. (1972). "How Language is Conveyed by Script". in J. F. Kavanach and I. G. Mattingly (Eds.). **Language by Ear and by Eye**. 117-124. The MIT Press.

Lupker, S. J. (1979). "On the Nature of Perceptual Information during Letter Perception". **Perception and Psychophysics**, 25, 303-312.

Martin, S. E. (1972). "Nonalphabetic Writing System: Some Observations". in J. F. Kavanach and I. G. Mattingly (Eds.). **Language by Ear and by Eye**. 81-102. The MIT Press.

Massaro, D. (1980). "How Does Orthographic Structure Facilitate Meaning?". in J. F. Kavanach and R. L. Venezky (Eds.). **Orthography, Reading and Dyslexia**. 193-209. Baltimore: University Park Press.

——— (1984). "Building and Testing Models of Reading Processes". in P. D. Pearson (Ed). **Handbook of Reading Research.** 111-146. New York: Longman.

McClelland, J. L. and Rumelhart, D. E. (1981). "An Interactive Activation Model of Context Effects in Letter Perception. Part I. An Account of Basic Findings". **Psychological Review**, 88, 375-407.

McCuster, L. K.; Gough, P. B. and Bias, R. G. (1981). "Word Recognition Inside out and Outside in". **Journal of Experimental Psychology: Human Perception and Performance**, 7, 538-551.

Morton, J. (1969). "Interaction of Information in Word Recognition". **Psychological Review**, 76, 165-178.

——— (1979). "Facilitation in Word Recognition: Experiments Causing change in the Logogen Model". In P. A. Kolars; M. Wrolstad; and H. Bouma (Eds.). **Processing of Visible Language I.** New York: Plenum.

Morton, J. and Patterson, K. (1980). "A New Attempt at an Interpretation, or an Attempt at a New Interpretation". in M. Coltheart; K. Patterson and J. C. Marshall (Eds.). **Deep Dyslexia.** 91-118. London: Routledge and Kegen Paul.

——— (1985). "Critisizing Dual Route-Theory: Missing the Point". **The Behavioral and Brain Sciences**, 8, 718.

Nelson, T. M. and Ladan, C. J. (1976). "Judgement of Meaningfulness of Chinese Characters by English-Speaking Observers". **Visual Language**, 10, 129-143.

Newnham, R. (1973). **About Chinese.** Maryland: Penguin Books Inc.

Norman, J. (1988). **Chinese.** New York: Cambridge University Press.

Norris, P.; and Brown, G. (1985). "Race Models and Analogy Theories: A Dead Heat? Reply to Seidenberg". **Cognition**, 20, 155-168.

Nguy, T. V. H.; Alland, F. A. and Bryolen, M. P. (1980). "Laterally Effects for Chinese

Characters: Differences Between Pictoral and Nonpictoral Characters". **Canadian Journal of Psychology**, 34, 270-273.

Patterson, K. E. and Morton, J. (1985). "From Orthography to Phonology: an Attempt at an Old Interpretation". in K. E. Patterson; J. C. Marshall; and M. Coltheart (Eds.). **Surface Deslexia**. 335-359.

Pulleyblank, E. G. (1984). **Middle Chinese: A Study in Historical Phonology.** University of British Columbia Press.

Rankin III, B. K., Siegel, S.; McClelland, A. and Tan, J. L. (1966). **A Grammar for Component Combination in Chinese Characters.** Washington.

Rayner, K. and Posnansky, C. (1978). "Stages of Processing in Word Identification". **Journal of Experimental Psychology: General**, 107, 64-80.

Rayner, K. (1981). "Eye Movements and the Perceptual Span in Reading". **Reading Research: Advances in Theory and Practice**, 1, 145-163.

——— (Ed.). (1983). **Eye Movements in Reading: Perceptual and Language Processes.** New York: Academic Press.

Rayner, K. and Duffy, S. A. (1988). "On-line Comprehension Processes and Eye Movements during Reading". **Reading Ressearch: Advances in Theory and Practice**, 6, 13-66.

Reed, S. K. (1973). **Psychological Processes in Pattern Recognition.** New York: Academic Press Inc..

Rips, L. J.; Smith, E. E.; Shoben, E. J. (1975). "Set-Theoretical and Network Models Reconsidered: A Comment on Hollam's Features and Semantic Memory". **Psychological Review**, 82, 156-157.

Rozin, P.; Poritsky, S.; and Stotsky, R. (1971). "American Children with Reading Problems Can Easily Learn to Read English Represented by Chinese Characters". **Science**, 171, 1264-1267.

Rumelhart, D. E. (1977). "Toward an Interactive Model of Reading". **Attention and Performance**. VI, 573-603.

Sakamoto, T. and Makita, K. (1973). in J. Downing (Ed.). **Comparative Reading: Cross-National Studies of Behavior and Processes in Reading Writing**. 440-465. New York: The Macmillan Company.

Samuels, S. J. and Kaml, M. L. (1984). "Models of the Reading Process". in P. D. Pearson (Ed.). **Handbook of Reading Research**. 185-224. New York: Longman.

Sasanuma, S.; Itoh, M.; Kobayashi, Y.; and Mori, K. (1977). "Tachistoscopic Recognition of Kana and Kanji Words". **Neuropsychologia**, 15, 547-553.

Sasanuma, S. (1980). "Acquired Dyslexia in Japanese: Clinical Features and Underlying Mechanisms". in M. Coltheart; K. Patterson; and J. C. Marshall (Eds.). **Deep Dyslexia**. London: Routledge and Kegan Paul.

Segui, J.; Mehler, J.; Frauenfelder, U. and Morton, J. (1982). "The Word Frequency Effect and Lexical Access". **Neuropsychologia**, 20, 615-628.

Seidenberg, M. S.; Wates, G. S.; Barnes, M.; and Tanenhaus, M. K. (1984). "When does Irregular Spelling or Pronunciation Influence Word Recognition?". **Journal of Verbal Learning and Verbal Behavior**, 23, 384-404.

Seidenberg, M. S. (1985). "The Time-Course of Phonological Code Activation in Two Writing Systems". **Cognition**, 19, 1-30.

———— (1985a) "Constraining Models of Word Recognition". **Cognition**, 20, 169-190.

———— (1985b). "The Time Course of Information: Activation and Utilization in Visual Word Recognition". **Reading Research: Advances in Theory and Practice**, 5, 199-252.

Serruys, P. L.-M. (1973). "A Review of the Etymologies of 3000 Chinese Characters in Common Usage". **Journal of Chinese Linguistics**, 1, 479-492.

Shen, E. (1972). "An Analysis of Eye Movement in the Reading of Chinese". **Journal of Experimental Psychology**, 10, 158-183.

Shiffrin, R. M. and Atkinson, R. C. (1969). "Storage and Retrieval Processes in Memory". **Psychological Review**, 76, 179-193.

Stern, J. A. (1978). "Eye Movements, Reading, and Cognition". in J. W. Senders; D. F. Fisher; and R. A. Montry (Eds.). **Movements and Higher Psychological Functions Vol. 2**. Hillsdale: Lawrence Erlbaum Associates, Publishers.

Sugishita, M.; Iwata, M.; Toyokura, Y.; Yoshioka, M.; and Yamada, R. (1978). "Reading of Ideograms and Phonograms in Japanese Patients after Partial Commissurotomy". **Neuropsychologia**, 16, 417-426.

Suzuki, T. (1975). "On the Twofold Phonetic Realization of Basic Concepts: In Defense of Chinese Characters in Japanese". in F.C.C. Peng (Ed.). **Language in Japanese Society: Current Issues in Sociolinguistics**. 175-192. University of Tokyo.

Taft, M. (1985). "The Decoding of Words in Lexical Access: A Review of the Morphographic Approaches". **Reading Research: Advances in Theory and Practice**, 5, 83-123.

Tanenhaus, M. K. (1988). "Psycholinguistics: an Overview". in F. J. Newmey (Ed.). **The Cambridge Survey....** 1-37.

Taylor, I. and Taylor, M. M. (1983). **Psychology of Reading**. New York: Academic Press.

Treiman, R. A.; Baron, J. and Luk, K. (1981). "Speech Recoding in Silent Reading". **Journal of Chinese Linguistics**, 9, 116-125.

T'sou, B. K. Y. (1981). "A Sociolinguistic Analysis of the Logographic Writing System of Chinese". **Journal of Chinese Linguistics**, 9, 1-19.

Tzeng, O. J. L. and Hung, D. (1980). "Reading in Nonalphabetic Writing System: Some Experimental Studies". in Kavanach and Venezky (Eds.). **Orthography, Reading,**

and Dyslexia. 211-226. Baltimore: University Park Press.

Tzeng, O. J. L.; Hung, D. L. and Wang, W. S-Y (1977). "Speech Recoding in Reading Chinese Characters". **Journal of Experimental Psychology: Haman Learning and Memory**, 621-630.

Tzeng, O. J. L. and Hung, D. L. (1981). "Linguistic Determinism: A Written Language Perspective". in O. J. L. Tzeng and H. Singer (Eds.). **Perception of Print: Reading Research in Experimental Psychology**. 29-64. New Jersey: Lawrence Erlbaum Associates Publishers.

Tzeng, O. J. L. and Wang, W. S-Y. (1983). "The First Two R's". **American Scientists**, 71, 238-243.

Tzeng, O. J. L. and Wang, W. S-Y. (1984). "In Search of a Common Neurocognitive Mechanism for Language and Movement". **American Journal of Physiology**, 246, R904-R911.

Tzeng, O. J. L.; Hung, D. C.; Chen, S.; Wu, J.; Hsi, M-S. (1986). "Processing Chinese Logographs by Chinese Brain Damaged Patients". in H. S. R. Kao; G. P. van Galen; R. Hoosain (Eds.). **Graphonomics**. 357-374.

Unger, J. M. (1987). **The Fifth Generation Fallacy: Why Japan is Betting its Future on Artificial Intelligence**. New York: Oxford University Press.

Venesky, R. C. and Massaro, D. W. (1987). "Orthographic Structure and Spelling-sound Regularity in Reading English Words". in A. Allport; D. Mackay; W. Prinz; E. Scheerer (Eds.). **Language Perception and Production: Relationships between Listening, Speaking, Reading and Writing**. 159-179. London: Academic Press.

Verschueren, J. (1985). **What People Say They Do With Words**. New Jersey: Ablex Publishing Cooperation.

Wang, F.-C. (1935). "An Experimental Study of Eye Movements in the Silent Reading of Chinese". **Elementary School Journal**, 35, 527-539.

Wang, W. S-Y. (1969). "Competing Changes as a Cause of Residue". **Language**, 45, 9-25.

———— (1971). **Modern Language Journal**, 55, 187-188.

———— (1981). "Language Structure and Optimal Orthography". in O. J. L. Tzeng and H. Singer (Eds.). **Perception of Print: Reading Research in Experimental Psychology**. 223-236.

———— (1978). "Proceedings of the CLTA Panel on Chinese Characters". **Journal of Chinese Linguistics**, 6, 268-271.

———— (1973). "The Chinese Characters". **Scientific American**, 228, 50-60.

———— (1979). "Language Change: A Lexical Perspective". **Annual Review of Anthropology**, 8, 353-371.

Wold, A. H.(1978). **Decoding Oral Language**. London: Academic Press Inc.

Woon, W-L. (1979). "A Synchronic Phonology of Hainan Dialect". **Journal of Chinese Linguistics**, 7. 65-100.

Yau, S-C. (1983). "Temporal Order in the Composition of Archaic Chinese Ideograms". **Journal of Chinese Linguistics**, 11, 187-213.

Yee Chiang (1973). **Chinese Calligraphy: An Introduction to Its Aesthetic and Technique**. Massachusetts: Harvard University Press.

Yeh, I. S. and Liu, I. M. (1972). "Factors Affecting Recognition Threshold of Chinese Characters". **Acta Psychologica Taiwannica**. 14, 113-117.

Yik, W. F. (1978). "The Effect of Visual and Acoustic Similarity on Short-term Memory for Chinese Characters". **Quarterly Journal of Experimental Psychology**, 30, 487-494.

Yuan, X. Y. and Xu. D. J. (1989). "汉字贵在无形态". People's Daily, March 29.

Zaidel, E. (1978). "Lexical Organization in the Right Hemisphere". In P. A. Buser and A. Rougeul-Buser (Eds.). **Cerebral Correlates of Conscious Experience.** Amsterdam: Elsevier/North Holland Biomedical Press.

——— (1981). "Phonological Encoding and Ideographic Reading by the Disconnected Right Hemisphere: Two Case Studies". **Brain and Language**, 14,, 205-234.

Zhou, Youguang. (1978). "To What Degree are the 'Phonetics' of Present-day Chinese Still Phonetic". **Zhongguo Yuwen**, 2, 172-177.