LANGUAGE PROCESSING IN CHINESE
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# Deep and Surface Dyslexia in Chinese

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A study of 11 Chinese brain-damaged patients with reading disorders indicates that reading aloud a nonalphabetic script, like reading alphabetic scripts, can be accomplished using two distinct routines: one which associates a whole written word with its complete pronunciation, and one which utilises parts of the written word. Each routine can be selectively impaired by brain-damage, resulting in different patterns of reading disability, i.e. "deep" and "surface" dyslexia. These data are consistent with the independent neural organisation of each routine, and the generality of the two-routine model for reading alphabetic and nonalphabetic scripts.

Studies of acquired disorders of reading Chinese have been the subject of intermittent reports since Lyman's pioneering paper in 1938 (Lyman, Kwan, & Chao, 1938). These studies have been confined to issues of the neural anatomy of Chinese reading disorders (Lyman, et al., 1938; Wang & Li, 1959; Tang, 1978; Hu, Zhu, & Wu, 1983; Li, Hu, Zhu, & Sun, 1984; Hu, Zhu, & Liu, 1986); clinical classification - for example, whether dyslexia is accompanied by dysgraphia (Wang & Tang, 1959; Tang, 1978; Wang & Li, 1981; Li, et al., 1984; Hu, et al., 1986); the relationship between speaking ability and reading capacity (Hu et al., 1983); and whether the reading impairment was at the level of words or at the level of sentences (Hu, et al., 1986). Little attention has been paid to specific *types* of dyslexia, and the potential functional dissociations these might reveal.

Recent studies of acquired disorders of alphabetic reading have revealed distinct types of dyslexia, which are held to be the consequences of selective deficits to components of the reading process. These findings support models of reading incorporating at least two, functionally and neurally separable, routines: a lexical routine that maps whole written words onto their pronunciations, or a sublexical routine that maps letters onto phonemes. (Marshall & Newcombe, 1973; Patterson, 1981). However, since both models and data are based on alphabetic readers and it is unclear which aspects of the reading process are common to all scripts and which are script-dependent. In this study, we describe for the first time the types of dyslexia found in Chinese readers using modern neuropsychological techniques. Although Chinese script is based on characters standing for words rather than on letters standing for sounds, evidence is presented that one group of patients suffer a selective deficit to a routine that maps whole characters onto pronunciations, and that a second group suffer an impairment to a sublexical routine that utilises the phonetic radicals that make up characters.

Recent models claim that skilled adults can read words aloud in two fundamentally distinct ways. (1) By means of a lexical procedure that associates a letter string as a whole with a meaning and a whole-word pronunciation. This is the fast preferred routine for skilled adult readers. (2) By means of a sublexical procedure, that associates single letters, or small groups of letters, with separate syllables or phonemes (the component sounds of a word), which then have to be assembled to yield the pronunciation of the whole word. This routine is used for reading new words and novel letter strings in adults, and is held to be a necessary stage in the development of reading skills in children (Coltheart, 1982; Frith, 1985; Seymour & MacGregor, 1984).

The precise operation of the sublexical routine is disputed. Mapping by rule from one or two letters onto single phonemes has been advocated (Coltheart, Besner, Jonasson, & Davelaar, 1979); while Shallice and McCarthy (1985) prefer sets of correspondences among units of various sizes. A single, lexical analogy procedure, backed up by grapheme-phoneme correspondences, has been suggested by Marcel (1980) and Kay and Marcel (1981); while a single procedure for reading both words and non-words has been advocated by Seidenberg and McClelland (1989).

Support for the model has been adduced from selective impairments of reading performance consistent with a deficit to one or other reading routine (Marshall & Newcombe, 1973; Patterson, 1981; Coltheart, 1982; etc). One class of patient makes characteristic regularisation errors in reading. For example, the patient HTR (Shallice, Warrington, & McCarthy, 1983) read GAUGE as "gorge"; other reported patients read GONE with a long "o" (as in BONE) and PINT with a short "i" (as in HINT). However, these patients are able to read aloud correctly both regularly spelled words and novel letter strings (pseudo-words) (Shallice, et al., 1983; Howard & Franklin, 1987), though they have particular difficulty with irregularly spelled words like PINT, (Coltheart, 1982), and in general, accurate reading depends on the degree of regularity, so that words with exceptional spellings, like COLONEL and YACHT, are hardest (Shallice, et al., 1983). This pattern of impairments is called "surface dyslexia" (Marshall & Newcombe, 1973) and is predictable from a deficit to the whole word routine, but where the routine for mapping letters onto phonemes is intact. The two critical indicators of this impairment are thus (1) regularisation of irregularly-spelled words and (2) poorer performance reading irregular words. [However, it should be noted that Shallice and his colleagues (see Shallice 1988, Chapter 5, for a review) have identified a further class of patients, who are able to read at least mildly irregular words, especially if these words are also familiar - like HAVE and GIVE. These patients, called "phonological readers" by Shallice, are often unable to give the meaning of words they have read correctly. The patient M.P., reported by Bub, Cancelliere, and Kertesz (1985), is such a case].

A second class of patient, by contrast, does not make regularisation errors, and reads irregularly-spelled words as well as regularly-spelled ones; however, these patients are unable to read novel letter strings (Marshall & Newcombe, 1973). These patients fall into two distinct subclasses. In the first, termed "phonological" alexia or dyslexia (Beauvois & Derouesne, 1979), the reader will read real words accurately, and indeed may have very good reading skills for real words (Campbell & Butterworth, 1985). This pattern of impairments is taken as evidence that the sublexical routine has been impaired, while mapping from whole words is relatively intact.

A second subclass has been termed "deep dyslexia" (Marshall & Newcombe, 1973). These patients are also unable to read novel letter strings, but whereas phonological alexics read real words accurately, these patients misread a word as one with a similar meaning. For example, the patient GR read DINNER as "food", and UNCLE as "cousin" (Coltheart, 1982). While spelling regularity is not a critical variable in determining reading accuracy for these patients, word meaning is: thus deep dyslexics are poorer at reading abstract than concrete words, and function words than nouns, verbs or adjectives (Coltheart, 1980). For deep dyslexic patients, although the sublexical routine is seriously impaired, the lexical routine has not been entirely spared: the presence of meaning-related errors, and the effects of meaning variables on reading accuracy, have suggested to Marshall and Newcombe (1973) and others that the lexical routine involves the mediation of the semantic system, rather than a "direct routine" from lexical orthography to whole word pronunciation. The presence of semantic errors and poor abstract word reading may therefore indicate additional deficits in the semantic system itself. Newcombe and Marshall (1980a,b) further speculate that in normal readers the sublexical routine may act as a check on the output of the lexical routine. That is, the lexical routine produces "food" for DINNER, while the sublexical routine will produce the phonologically incompatible output , "dinner", and thus the reader will know that "food" cannot therefore be correct. Since the deep dyslexic patient cannot use the sublexical routine, this error will go through unchallenged.

Attempts to test the generalizability of the two-routine model to readers of nonalphabetic scripts has been limited to studies of Japanese patients. These studies show a selective deficit of the ability to read Kana, a script that represents syllables, while the ability to read Kanji, a script based on Chinese logographs, is preserved (Sasanuma, 1980). It was believed that reading Kanji is basically a lexical process, and the details of reading impairment of Kanji have not been analyzed further in terms of the two-routine model. Nevertheless, it is important to note that Kanji is different from the characters used by Chinese readers. A character used by Chinese usually has one pronunciation (with some exceptions), while a Japanese Kanji usually has two pronunciations: an On-reading which is based on Chinese sound, and a Japanese Kun-reading, but sometimes several On-readings. A Japanese reader has to decide which reading should be employed against the background where the particular character is set. As far as the phonetic component in Kanji (the structural element which may provides the reader with the clue of how the character is to be pronounced) is concerned, it is not as reliable as that in Chinese characters.

Because Chinese script is nonalphabetic, it is widely assumed that characters contain no sublexical information as to their pronunciation. This is not the case. Most characters, including the vast majority of common characters, contain a "phonetic radical" which can indicate how the character is to be pronounced. A phonetic radical, in isolation, is like a normal character that stands for a word or morpheme (Sampson, 1985). Phonetic radicals are used in the creation of new characters for loan words and can be used to construct pronounceable pseudo-words. For historical reasons, these radicals are often an unreliable guide to phonology: some ("*regular*") characters are pronounced like the radical in isolation, other ("*irregular*") characters are not (see Table 1). The reliability and accuracy of representing sound through the phonetic radical has been examined (Yin, 1991). Thirty-six percent of phonetic radicals completely represent the characters' sound. Forty-eight percent of phonetic radicals partially represent the sound. Sixteen percent of phonetic radicals do not represent the sound at all. Clearly, this representation of the characters' sound through phonetic radical can not be neglected, but the accuracy of this representation should also be taken into consideration when thinking about how reading is achieved.

Although this way of encoding the spoken language is very different from alphabetic scripts, it is nevertheless possible that a sublexical routine to phonology is available to normal Chinese which makes use of clues from phonetic radicals. If this is so, then one should find analogues of the dyslexias that result from the selective impairment of either the lexical or the sublexical routines to phonology.

A series of reading tests were therefore devised to examine the possibility that Chinese dyslexics (1) made errors analogous to alphabetic dyslexics, and (2) were sensitive to the analogous critical variables of regularity and of lexicality (that is, real words vs. pseudo-words). If the two routines are employed by Chinese readers, and each routine can be selectively impaired, then the following patterns of reading disturbance should be observed.

| Analogue of Deep Dyslexia[1] | Analogue of Surface Dyslexia |
|---|---|
| 1. Many semantic errors | 1. No or few semantic errors |
| 2. No regularisation errors | 2. Many regularisation errors |
| 3. Comparable accuracy for regular and irregular characters | 3. Regular characters read more accurately |
| 4. Pseudo-words unreadable | 4. Pseudo-words readable |

**Table 1**
Example of regularization.

| Regular character | Irregular character |
| --- | --- |
| 評 | 秤 |
| Pronunciation: [Píng]<br>Meaning: comment | Pronunciation: [Chèng]<br>Meaning: steelyard |

**Phonetic radical**

平

Pronunciation: [Píng]

**Regularization**

秤 [Chèng] --- pronounced as [Píng]

## Method

### *Subjects*

Eleven brain-damaged right-handed patients were examined from the Tiantan Hospital in Beijing and the First Hospital of the Beijing Medical University. All were native speakers of Mandarin Chinese. The basic conditions of these patients are as follows:

QXS: He had been an engineer with a university degree. He suffered cerebral arteriosclerosis for years. Since symptoms such as bad memory had been become more and more severe, he went to hospital for treatment in 1987. The CT scan showed that the ventricles and sulci were enlarged. Meanwhile, SPECT (Single Photon Emission Computed Tomography) demonstrated RCBF (Regional Cerebral Blood Flow) decreased in the area of MCA (Middle Cerebral Artery) in the left hemisphere. He was diagnosed as having encephalatrophy with more severe condition in the left hemisphere.

LWY: He was a cadre of a company with a secondary school education. In June of 1988, he suffered cerebral vascular occlusion in the left hemisphere. The CT scan showed that there was a low-density region in the conjunctive area of the temporal, parietal and occipital lobes. The lesion extended backwards to the pole of the occipital lobe.

LYM: Before retirement, he was a statistician. He also had a secondary school education. He suffered a meningioma in the left hemisphere. In 1986, he went to Beijing medical hospital to have the brain tumour removed. The CT scan showed a 6 x 4 cm size tumour in the left temporal lobe.

LSH: He was a technician who had graduated from a polytechnic. In February of 1988, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed a low-density area in the conjunctive area of the temporal, parietal and occipital lobes in the left hemisphere.

LQF: Before retirement, he was an accountant with a secondary school education. In 1986, he had cerebrovascular occlusion in the left hemisphere. The CT scan showed that around the left basal ganglia there was a low-density area. Outside of the left corona radiata there was a spot of occlusion.

LZY: He was a worker with a secondary school education. In January of 1988, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed there was a lesion in the conjunctive area of the temporal, parietal and occipital lobes in the left hemisphere. Meanwhile, SPECT (Single Photon Emission Computed Tomography) demonstrated CBF (Cerebral Blood Flow) had decreased in the area of the temporal and occipital lobes in the left hemisphere.

WBY: He was a professor in a university. In 1985, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed some lesions located in the conjunctive area of the temporal, parietal and occipital lobes. At the time he was examined in 1989, he had recovered a lot of his language ability.

LSJ: He used to be a secondary school teacher with a degree from a polytechnic. In 1988, he suffered a cerebrovascular occlusion in the left hemisphere. The CT scan showed there was a large low-density region on the junction of the temporal, parietal and occipital lobes.

LLH: He was a professor at a university. In 1986, when visiting Italy his brain was badly damaged in a car accident. The CT scan showed that there was a destruction on the left frontal and temporal part of the skull, and the cerebral cortex underneath had also been damaged.

LDJ: She was a secondary school teacher with a university degree. In June of 1988, she suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed there were lesions in the left ganglia area and the left parietal and occipital area. Meanwhile, a MRI (Magnetic Resonance Imaging) scan showed that there were lesions in the post-parietal branch and angular gurus branch of MCA of the left hemisphere.

ZZG: He was a student at elementary school. He suffered from a kind of cerebral vascular malformation disease, called Moya Moya's disease. The CT scan made in August of 1988 showed that there was a lesion in the frontal lobe of the right hemisphere. Meanwhile angiography proved the diagnosis of Moya Moya's disease.

These eleven patients were found to have various degrees of language dysfunction. In addition to reading tests, their speaking, listening and writing abilities were also assessed. A variety of associations between disorders in reading and impairment of other language functions.

A brief summary of these patients are given in Table 2(a and b).

The neuroanatomy of these patients show the importance of the left hemisphere in reading Chinese. All of these eleven patients except one child had left hemisphere damage. Within the left hemisphere the lesions were mostly localized in conjunctive areas of the temporal, parietal and occipital lobes. These findings are consistent with previous studies on Chinese reading disorders (Lyman, et al., 1938; Wang, et al., 1959; Tang, 1978; Hu, et al., 1983; Li, et al., 1984; Hu, et al., 1986). There is thus no evidence that the supposedly pictorial nature of Chinese characters leads to localisation of function in the right hemisphere, where picture and visual object recognition is carried out.

An examination of the patients' comprehension, speaking, writing and reading abilities reveals 4 distinct clinical categories:

(1) *Pure alexia* - a reading disorder not accompanied by writing impairment, sometimes called alexia without agraphia. Patients LYM, QXS, WBY and LLH fell into this category.

(2) *Alexia with agraphia* - a reading disorder which is accompanied by writing disorder - manifested by patients LWY, LSH and LZY.

(3) *Alexia with agraphia and aphasia.* Patients ZZG, LDJ, LSJ and LQF showed language problems in addition to their reading and writing deficits.

It should be noted that the reading deficits accompanied a wide range of abilities in listening comprehension, speaking and writing, ranging from normal to very severely impaired.

**Table 2(a)**
Patient Summary.

| Name | Age | Sex | Onset | Etiology | Hemisphere | Location |
|---|---|---|---|---|---|---|
| QXS | 64 | M | Unknown | Cerebral arteriosclerosis | left | MCA* area |
| LWY | 53 | M | 1988 | Cerebrovascular occlusion | left | temporal occipital |
| LYM | 73 | M | Unknown | Meningioma | left | temporal |
| LSH | 55 | M | 1988 | Cerebrovascular occlusion | left | parietal, temporal occipital |
| LQF | 76 | M | 1986 | Cerebrovascular occlusion | left | BG* area CR* area |
| LZY | 28 | M | 1988 | Cerebrovascular occlusion | left | parietal, temporal occipital |
| WBY | 58 | M | 1985 | Cerebrovascular occlusion | left | parietal, temporal occipital |
| LSJ | 65 | M | 1988 | Cerebrovascular occlusion | left | parietal, temporal occipital |
| LLH | 62 | M | 1986 | Trauma | left | frontal, temporal |
| LDJ | 57 | F | 1988 | Cerebrovascular occlusion | left | parietal, occipital |
| ZZG | 12 | M | Unknown | Moya Moya's disease | right | frontal, parietal |

MCA: middle cerebral artery. BG: basal ganglia. CR: corona radiata.

**Table 2(b)**
Patient Summary.

| Name | Education level | Writing | Listening | Speaking |
|---|---|---|---|---|
| QXS | University | + | + | + |
| LWY | Secondary school | - | + | + |
| LYM | Secondary school | + | + | + |
| LSH | Polytechnic | - - | + | + |
| LQF | Secondary school | - - | + | + - |
| LZY | Secondary school | + - | + | + |
| WBY | University | + | + | + |
| LSJ | Polytechnic | - | + - | + |
| LLH | University | + | + | + |
| LDJ | Secondary school | - | + | - - |
| ZZG | Elementary school | - - | + | - |

Notes:
Writing
+: could write sentences without difficulty
+-: unable to write some common characters
-: unable to write many common characters, but able to write their own names and addresses
--: able to write few or no characters

Listening
+: able to understand all questions asked by the examiner
+-: patient could follow simple commands, but failed to understand some questions

Speaking

+-: could describe common objects, and could express him or herself freely

+-: unable to name some common objects with abnormal hesitancy

-: great word finding difficulty

--: only a few words correctly produced, speech often incomprehensible

## *Reading tests*

Each patient was asked to read aloud 40 common regular characters, 21 common irregular characters, 12 common phonetic radicals and 14 pseudo-words. Pseudo-words were invented pictophonetic (two component) characters constructed from phonetic radicals in legal positions.Phonetic radicals typically take the same position in all the characters; such as, for example, 里 [lǐ], always appears on the right ( 理 "reason", pronounced [lǐ], 鯉 "carp" [lǐ], and 俚 "vulgar" [lǐ]). In the pseudo-words of this study, all the radicals appeared in their normal position on the right.

Regularisation errors were identified according to the principle described above. Errors were classified as semantic, if they were similar in meaning or related in meaning to the target; e.g. in 别 "leave" [bié] read as 分 "separate" (verb) [fēn], the errors were similar in meaning; while for 子 "child" [zǐ] read as 小 "little" [xiǎo], the error was related in meaning.

Patients making regularisation errors were classified as "surface" dyslexics, while the remainder were classified as "deep" dyslexics. The presence of semantic errors was not sufficient to identify deep dyslexics, since all Chinese readers make semantic errors. This unusual phenomenon may be due to the unavailability of a sublexical phonemic check on output for many characters. In an experiment with normal subjects, Yin (1991) found that the presence of a phonetic radical is usually sufficient to suppress a semantic error. The frequency of these errors was recorded and analyzed.

## Results

The proportions of each type of error are give in Table 3. The percentage correct for each type of character is given in Figure 1. The patients classified as surface dyslexics made a high proportion of regularisation errors (25% to 75%). Both groups made semantic errors, but a significantly higher proportion were made by the deep dyslexics ($t$=5.28, $df$=7, $p$<.005). There were further differences between the semantic errors made by each groups. The "deep" dyslexic group made semantic errors no matter the target character (the character they were required to read aloud) had a phonetic radical or not. While the "surface" group made semantic errors only when the target character had no phonetic radical.

**Table 3**
Reading errors.

| **Types** | **Patients** | **Semantic Errors** | **Regularization** |
|---|---|---|---|
| DEEP DYSLEXIA | QXS | 24 % | 0 |
| | LYM | 45 % | 0 |
| | LLH | 54 % | 0 |
| | ZZG | 57 % | 0 |
| | LDJ | 50 % | 0 |
| | LWY | 47 % | 0 |
| | LSJ | 41 % | 0 |
| SURFACE DYSLEXIA | LSH | 17 % | 46 % |
| | LZY | 21 % | 53 % |
| | LQF | 14 % | 25 % |
| | WBY | 0 | 75 % |

(PERCENTAGE OF TOTAL ERRORS)

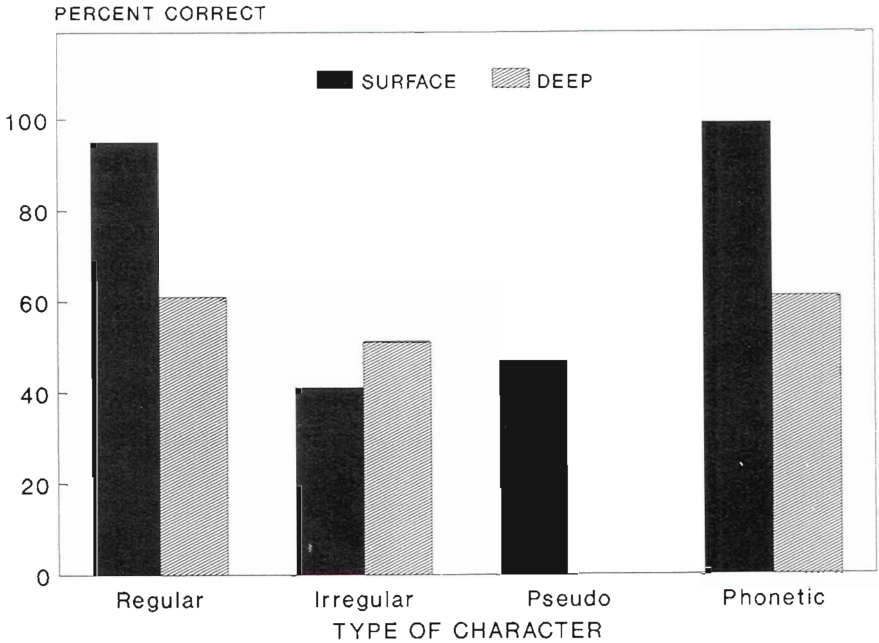


**Figure 1.**

Because many Chinese characters have a component or "signific" (Sampson, 1985) which has the function of indicating or implying the category of meaning of the character. Therefore a question is raised here: do the semantic errors made by patients have some relationships with the significs of the characters they read?

It was found that most semantic errors happened with the single-graph characters which have not got a signific in their construction (75 percent of all characters which produced semantic errors were single-graph characters). However, 62 percent of all the characters which had a signific in the structure produced semantic errors. On the whole, there were only 12 percent of all semantic errors which had a relationship to the signific of the characters. Some examples of the relationship between semantic errors and significs are as follows: 秧 "seedling", [yāng], was read as 苗 "young plant", [miáo]. 禾 is a signific which indicates something relevant to grain, especially rice. The meaning of 禾 is grain. It's pronunciation is [hé]. 軀 "trunk", [qū], was read as 体 "body", [tǐ]. 身 is a signific which indicates something relevant to a body. The meaning of 身 is human body. It's pronunciation is [shēn]. 锯 "saw", [jù] was read as 锤 "hammer", [chuí]. 钅 is a signific which indicates something is made from metal. 钅 is no longer a single-graph character as many significs are. 钅 is evolved from a single-graph character 金 [jīn] which means "gold" or "metal".

All deep dyslexic patients were completely unable to read pseudowords aloud. On the other hand, the surface dyslexics were able to read better than 40% of them on average. This difference is partly explained by reading performance on phonetic radicals in isolation.

The deep dyslexics showed comparable performance on regular and irregular characters, while the surface dyslexics were significantly better on regular characters ($t=3.06$, $df=3$, $p<.05$).

One case of deep dyslexia provided a unique opportunity to study the word by word extent of an acquired reading problem. Patient LSJ was an active learner. When he left hospital, he did not rest passively waiting for recovery, rather he adopted an active strategy to help his recovery by learning. He spent much of his time at home reading a dictionary (Xin Hua Zi Dian, 1971) to see how many characters he failed to read, and how many characters he still retained the ability to read. Each character on every page of the dictionary was marked by him according to his reading results. The marks he used included circles, ticks and underlinings. Red circles indicated the characters which he could still correctly read, i.e. he knew both the meaning and the sound of them; the black circles marked the characters which he felt looked strange. The ticks were used to stand for the characters whose meanings he knew (either precisely or roughly) but which he could not read aloud; the underlinings were used to signify the characters for which knew neither the meaning nor the pronunciation.

The dictionary used by LSJ has a vocabulary of about 11,000 characters. There were 490 characters which were marked with red circles, indicating that he knew both meaning and pronunciation. One hundred and three characters, marked by black circles, looked strange to him. However, he felt he knew the meaning of 5,570 characters marked by ticks, which he failed to pronounce. Apparently, LSJ retained in his vocabulary 6,060 characters whose meaning he still knew (though not all precisely). Thus, only for 8 % of his total reading vocabulary could LSJ get the correct pronunciation (490 / 6060 = 0.08). This showed that knowledge of the sound of characters could be dissociated from knowledge of meaning.

Further analysis performed on LSJ's data revealed an interesting double dissociation. LSJ could read some 18 characters when they were in combination-forms, but he failed to read them as single graphs, even though those single-graphs were used in combination-forms which he could successfully pronounce, and moreover, the pronunciation of those single-graphs and combination-forms were the same. On the other hand, LSJ could read 82 characters as single-graphs, but failed to read them in combination-forms, again despite their having the same pronunciation.

This double dissociation suggests that LSJ always read characters as wholes, and could not exploit the phonetic radicals in attempts to pronounce combination-forms. That is to say, if a combination-form which he could pronounce, contained a phonetic radical, he was not necessarily able to use this fact to read aloud the isolated radical; on the other hand, if he could pronounce a phonetic radical, he could not always make this information available to attempt a pronunciation of a form he did not recognise. Thus this patient provides us with remarkable evidence of a relatively preserved lexical routine in the absence of a sublexical routine. As would be expected from the dictionary study, this patient falls squarely into our classification of Deep Dyslexia, making a high proportion of semantic errors, and no regularisation errors (Yin, 1991).

## Discussion

The results of the present study demonstrate that patterns of impairment quite analogous to those of alphabetic dyslexics can be found in readers of a nonalphabetic script. Seven of the patients showed symptoms consistent with a selective disorder in the use of sublexical information in reading, but relatively spared ability to read real words as a whole. At the same time, four patients were able to use sublexical information, and indeed appeared to rely on it even where inappropriate: that is, those characters where only an intact lexical routine would have yielded a correct pronunciation were read sublexically.

Regularisation and semantic errors turned out to be highly reliable predictors of overall performance on the four types of character.

However, these data do not mean that readers of nonalphabetic scripts use precisely the same processes as alphabetic readers. With respect to the sublexical routine, they clearly cannot employ grapheme-phoneme rules, at single phoneme or higher levels: phonetic radicals provide clues to the pronunciation of the whole word, rather than to a part of it. Moreover, it is not clear from these data how similar the Chinese lexical routine is to its alphabetic counterpart. Marhsall and Newcombe (1973) assumed that the alphabetic lexical routine necessarily involves a semantic interpretation of the written word; a more direct mapping from whole words to pronunciation, without the involvement of meaning (which would support, for example, the ability to read correctly irregular words without understanding them) is still controversial (See Bub, et al., 1985; Howard and Franklin, 1987; for discussion). It still needs to be established whether the lexical routine for Chinese readers necessarily involves semantic recoding.

Newcombe and Marshall (1980a,b) have further suggested that the independent availability of a phonological representation of the written word can serve as a check on the output of a lexical routine that utilises the semantic system. They claim that the semantic system in deep dyslexics has become unstable, and because the nonlexical routine is unable to deliver an independent check, semantic errors are likely to be produced. This study provided evidence that the presence of a phonetic radical in a character can prevent or reduce the likelihood of semantic error, because surface dyslexics who have a demonstrable capacity to make use of phonetic radicals in reading characters aloud made no semantic errors when there was a phonetic radical in the character.

Despite the very different ways in which Chinese and alphabetic writing systems represent their languages, the reading processes that decode them appear to have the same broad underlying cognitive architecture.

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## Footnote

1.Two further symptoms of alphabetic deep dyslexia, noted above, were not tested: the effects of concreteness and the effects of grammatical category.

## References


Beauvois, M-F. & Derouesne, J. (1979) Phonological alexia: Three dissociations. *Journal of Neurology, Neurosurgery and Psychiatry*, *42*, 1115-1124

Bub, D., Cancelliere, A. & Kertesz, A. (1985) Whole-word and analytic translation of spelling-to-sound in a non-semantic reader. In Patterson, K. E., Marshall, J. C. & Coltheart M. (eds), *Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Reading*. London, Erlbaum.

Campbell, R. & Butterworth, B. (1985) Phonological dyslexia and dysgraphia in a highly literate subject: A development case with associated deficits of phonemic processing and awareness. *Quarterly Journal of Experimental Psychology*, *37A*, 435-475

Coltheart, M. (1980) Deep dyslexia: A review of the syndrome. In Coltheart, M., Patterson, K. E. & Marshall, J. C. (Eds), *Deep Dyslexia*. London, Routledge & Kegan Paul. 22-47

Coltheart, M. (1982) The psycholinguistic analysis of the acquired dyslexias: Some illustrations. *The Philosophical transactions of the Royal Society of London*, *B298*, 151-164

Coltheart, M., Besner, D., Jonasson, J. & Davelaar, E. (1979) *Quarterly Journal of Experimental Psychology*, *31*, 489-507

Frith, U. (1985) Beneath the surface of developmental dyslexia. In Patterson, K. E., Marshall, J. C. & Coltheart M. (eds), *Surface Dyslexia: Neuropsychological and Cognitive Studies of Phonological Reading*. London, Erlbaum. 301-327

Howard, D. & Franklin, S. (1987) Three ways for understanding written words and their use in contrasting cases of surface dyslexia. In Allport, D.A., Mackay, D., Prinz, W. & Scheerer, E. (eds), *Language Perception and Production: Common processes in listening, speaking, reading and writing*. London, Academic Press. 340-366

Hu, C.Q., Zhu, Y.L. & Liu, A.L. (1986) A neurolinguistic study on reading disorders after brain damage. *Chinese Journal of Neurology and Psychiatry*, *19*, 26-29.

Hu, C.Q., Zhu, Y.L. & Wu, W.Z. (1983) The supporting effect of spoken language to written language -- A neurolinguistic analysis through cases of brain damage. *Acta Psychologia Sinica*, *3*, 349-353.

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

Li, X. T., Hu, C. Q., Zhu, Y. L. & Sun, B. (1984) Neurolinguistic analysis of Chinese alexia and agraphia. In Kao, H. S. R & Hoosain, R. (eds), *Psychological Studies of the Chinese Language*. Chinese Language Society of Hong Kong. 151-166.

Lyman, R. S., Kwan, S. T. & Chao, W. H. (1938) Left occipito-parietal brain tumour with observations on alexia and agraphia in Chinese and English. *The Chinese Medical Journal*, *54*, 491-515

Marcel, T. (1980) Surface dyslexia and beginning reading: a revised hypothesis of the pronunciation of print and its impairments. In Coltheart, M., Patterson, K. E. & Marshall, J. C. (Eds), *Deep Dyslexia*. London, Routledge & Kegan Paul. 227-258

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

Newcombe, F. & Marshall, J. C. (1980a) Response monitoring and response blocking in deep dyslexia. In Coltheart, M., Patterson, K. E. & Marshall, J. C. (Eds), *Deep Dyslexia*. London, Routledge & Kegan Paul. 160-175

Newcombe, F. & Marshall, J. C. (1980b) Transcoding and lexical stabilisation in deep dyslexia. In Coltheart, M., Patterson, K. E. & Marshall, J. C. (Eds), *Deep Dyslexia*. London, Routledge & Kegan Paul. 176-188

Patterson, K. E. (1981) Neuropsychological approaches to the study of reading. *British Journal of Psychology*, *72*, 151-174

Sampson, G. (1985) *Writing Systems*. Hutchinson Education, London.

Sasanuma, S. (1980) Acquired dyslexia in Japanese: Clinical features and underlying mechanisms. In Coltheart, M., Patterson, K. E. & Marshall, J. C. (Eds), *Deep Dyslexia*. London, Routledge & Kegan Paul. 48-90.

Seidenberg, M. S. & McClelland, J. (1989) A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*, 523-586

Seymour, P. H. K. & McGregor, C. J. (1984) Developmental dyslexia: A cognitive experimental analysis of phonological, morphemic and visual impairments. *Cognitive Neuropsychology*, *1*, 43-82 .

Shallice, T. *From Neuropsychology to Mental Structure*. Cambridge, Cambridge University Press, 1988.

Shallice, T. & McCarthy, R. (1985) Phonological reading: From patterns of impairment to possible procedures. In Patterson, K. E., Marshall, J. C. & Coltheart, M. (eds), *Surface Dyslexia*. London, Erlbaum. 361-397.

Shallice, T., Warrington, E. K. & McCarthy, R. (1983) Reading without semantics. *Quarterly Journal of Experimental Psychology*, *35A*, 111-138.

Tang, C.M. (1978) Alexia. *The Progress of disease in Nervous system*, *1*, 113-117.

Wang, X. D. & Li, J. (1981). Agraphia. *Chinese Journal of Neurology and Psychiatry*, *14*, 148-151

Wang, X. D. & Tang, X. J. (1959). Alexia. *Chinese Journal of Neurology and Psychiatry*, *5*, 180-187

Xin Hua Zi Dian (Chinese Dictionary), (1971). Shang-Wu Publishing House, Beijing.

Yin, W. (1991). *On reading Chinese characters -- an experimental and neuropsychol ogical study*. Unpublished Ph.D. thesis. University of London.