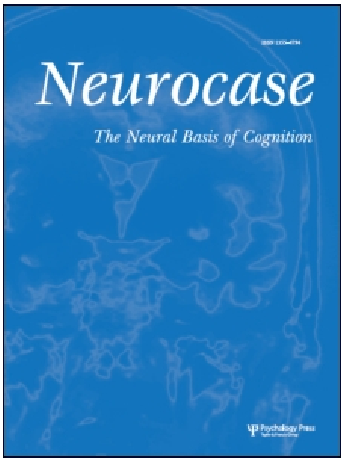

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Surface Dyslexia in Chinese

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Abstract

We report the oral reading performance of a Chinese anomic patient LJG, whose reduced confrontation naming was accompanied by impaired written word and spoken word comprehension. LJG's oral reading is significantly better than his comprehension of the same lexical items from written word and from spoken word input, although his oral reading is not flawless. We examined the effects of character regularity, frequency and concreteness on LJG's oral reading of single-character monosyllabic Chinese words. LJG displayed impairment when reading aloud irregular Chinese characters that have an unpredictable correspondence between their components and the pronunciation of the character as a whole. This deficit was particularly severe for irregular, low-frequency, abstract items. In addition, LJG produced a number of oral reading errors in which characters were assigned pronunciations appropriate to a character component rather than the character itself. We characterize LJG's oral reading as surface dyslexia. We argue that the oral reading of irregular Chinese characters is more prone to error than oral reading of regular Chinese characters following brain damage because of response competition at the level of phonological output.

Introduction

In a recent report, Weekes *et al.* (1997a) described a Chinese-speaking patient (YQS) with cerebrovascular disease who displayed impaired confrontation naming and reduced category fluency co-incident with intact oral reading of Chinese characters. Weekes *et al.* (1997a) called this pattern of performance anomia without dyslexia in Chinese. Weekes *et al.* (1997a) interpreted anomia without dyslexia in Chinese in terms of a two-pathway diagram of picture naming and oral reading. The triangular architecture of the Weekes *et al.* (1997a) diagram is similar to models of oral reading in English and Japanese (Patterson, 1990; Plaut *et al.*, 1996). In the Weekes *et al.* (1997a) framework, one pathway links the orthographic representation of a Chinese character to phonological output via semantic representations, and the other pathway connects orthography to phonology directly, i.e. by-passing semantic representations.

YQS performed normally on several tests of word comprehension, including written-word/picture matching, spoken-word/picture matching and picture/picture matching. We can therefore characterize YQS's language profile as anomia without semantic impairment. Thus, we know that Chinese speakers who are anomic without semantic impairment can display intact oral reading. However, we also know that Chinese speakers who are anomic without semantic impairment can be dyslexic. For example, Hu *et al.* (1983) compared the confrontation naming and oral reading of 16 patients with unimpaired written word and spoken word comprehension, and found that anomia was co-incident with dyslexia in approximately 75% of cases. Weekes *et al.* (1997b) reported three anomic patients without semantic impairment who made a variety of oral reading errors, including errors that were semantically related to the target, e.g. 猫 'mao(1)' *cat* → 'yang(2)' *sheep*; phonologically related to the target, e.g. 花 'hua(1)' *flower* → 'wa(4)' *socks*; or unrelated to the target, e.g. 畔 'pan(4)' *bank* → 'hong(2)' *red*. Thus, Chinese speakers who display anomia without semantic impairment can be dyslexic even though anomia and dyslexia in Chinese are dissociable deficits.

Anomia with semantic impairment is characterized by the production of semantic speech errors on confrontation naming tasks accompanied by errors in spoken word comprehension (Harley, 1995; Nickels, 1995). Semantic anomia is a characteristic feature of patients who have semantic dementia (Patterson and Hodges, 1992) or dementia of Alzheimer type (Bayles, 1982). Within these patient groups, there are several converging indicators of semantic impairment. These include written word and spoken word comprehension difficulties, reduced category fluency and semantic errors on object naming tasks. These patients also demonstrate poor performance on word/picture matching tasks with written word and spoken word input, typically making semantic errors such as pointing to a picture of a dog in response to the spoken word 'cat'.

Some studies of the word-processing skills of anomic patients with semantic impairment have found that despite impairment to written word and spoken word comprehension,

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oral reading of English words (e.g. Bayles *et al.*, 1982; Friedman *et al.*, 1992) and Japanese words (e.g. Sasanuma *et al.*, 1992) can be relatively well preserved. However, in other studies of the oral reading of DAT patients (e.g. Patterson *et al.*, 1994) and semantic dementia patients (e.g. Schwartz *et al.*, 1979; Patterson and Hodges, 1992; Breedin *et al.*, 1994; Graham *et al.*, 1994), there is an association between the severity of semantic impairment and impaired oral reading of low-frequency English irregular words (e.g. *pint*). Moreover, Howard and Franklin (1988) and Franklin *et al.* (1995) found that irregular words with abstract meanings (e.g. *indict*) are more prone to error for English speakers who have semantic impairment.

Irregular words of English have an unpredictable correspondence between the components of the word and the pronunciation of the word as a whole. When the patients reported by Patterson *et al.* (1994) read aloud low-frequency irregular words, they tended to produce regularization errors. Regularization errors in English are the most common pronunciations associated with the composite letters of an irregular word (e.g. *pint* read as 'p/ɪ/nt' instead of 'p/aɪ/nt'). An association between semantic impairment and impaired oral reading of irregular words has also been reported in Dutch (Diesfeldt, 1992), Italian (Miceli and Caramazza, 1993) and Japanese (Patterson *et al.*, 1995).

Patterson *et al.* (1995) reported a Japanese-speaking patient, NK, who had neurodegenerative disease and atrophy of the left temporal neocortex. NK's cognitive profile was characterized by progressive aphasia, anomia and semantic memory impairment. Patterson *et al.* (1995) found that NK displayed a deficit when reading aloud two character Kanji words that was particularly severe for low-frequency words with an unpredictable correspondence between the component characters and the pronunciation of the word itself. NK tended to produce Kanji word-reading errors in which she assigned a reading to one or more characters that is a legitimate pronunciation of the character in other contexts, but is not appropriate to the word in question. Patterson *et al.* (1995) called this type of error a legitimate alternative reading of components or 'LARC' error. Patterson *et al.* (1995) argued that NK made errors when reading aloud Kanji characters as a result of her semantic memory impairment. According to Patterson *et al.* (1995), alternative and usually more typical pronunciations of the components of a Japanese word will dominate the computation from orthography to phonology when there is a lack of semantic support to help the oral reading system settle on the correct, but atypical pronunciation of an irregular word. A very similar account of the oral reading impairments of DAT patients and semantic dementia patients when reading aloud low-frequency irregular English words has been advanced by Patterson and Hodges (1992) and colleagues (Graham *et al.*, 1994; Patterson *et al.*, 1994; Strain *et al.*, 1995; Plaut *et al.*, 1996).

In the Chinese script, there are many irregular single-character words that have an unpredictable correspondence between the components of the character and the pronunciation of the character as a whole. Compound characters are the most common type of Chinese character (Zhou, 1978). A compound Chinese character contains two or more components called radicals which sometimes give the reader information about the pronunciation of the character as a whole. A regular Chinese compound contains a phonetic radical which is congruent with the pronunciation of the character as a whole. For example, the regular character 评, pronounced 'ping(2)', is congruent with its phonetic component 平, which is also pronounced 'ping(2)'. However, the majority of compound characters (over 70%) can be considered irregular characters (Yin and Butterworth, 1992). This is because, for these characters, there is an unpredictable correspondence between character components and the pronunciation of the character as a whole. For example, the irregular character 秤, pronounced 'cheng(4)', is different to the pronunciation of the component 平, pronounced 'ping(2)'.

Yin (1991), and also Yin and Butterworth (1992), reported four Chinese speakers with cerebrovascular disease who showed a selective impairment when reading aloud irregular Chinese characters. These patients tended to make 'regularization' or, more precisely, LARC errors when reading aloud irregular Chinese characters. A LARC error in Chinese takes the form of giving an incorrect pronunciation to an irregular character that is appropriate to other characters containing the same component (cf. Patterson *et al.*, 1995). So, for example, if the irregular character 秤 is read aloud as 'ping(2)', this would be an LARC error in Chinese. There is evidence that semantic impairment is associated with the production of LARC errors in Chinese. For example, Yin (1991) reported patient LQF who was impaired on tests of word comprehension, spoken word production and word–picture matching. LQF also produced a very large number (over 90%) of LARC errors when reading aloud irregular characters. Yin (1991) also reported patient LSH, with milder impairment on tests of word comprehension, who made LARC errors when reading aloud irregular Chinese characters.

An association between semantic impairment and a tendency to produce LARC errors when reading aloud irregular characters suggests that semantic information might constrain the oral reading of irregular words in Chinese as it does in other scripts. This makes intuitive sense given that for the majority of Chinese characters the relationship between orthography and phonology is quite arbitrary. For the Chinese reader, simply knowing the names of the components of a character will not automatically afford the correct pronunciation of the character itself. Instead, the reader must 'know' the pronunciation of the whole character in order to read it aloud correctly.

Weekes *et al.* (1997a) argued that the pattern of anomia without dyslexia displayed by patient YQS showed that the oral reading of Chinese characters does not require access to the mappings between semantic representations and phonological output. Their claim was based on the finding that YQS could read aloud many hundreds of picture names despite being unable to name the pictures themselves. One limitation to this claim is that the characters YQS could read aloud were all by definition concrete words. That is, the words that YQS could read aloud were associated with a sensory referent (e.g. 铃 'ling(2)' *bell*). It is therefore unknown whether oral reading of abstract Chinese characters (e.g. 怕 pa(4) *afraid*) remains intact when access to the mappings between semantic representations and phonological output, or indeed when semantic representations themselves, become impaired following brain damage.

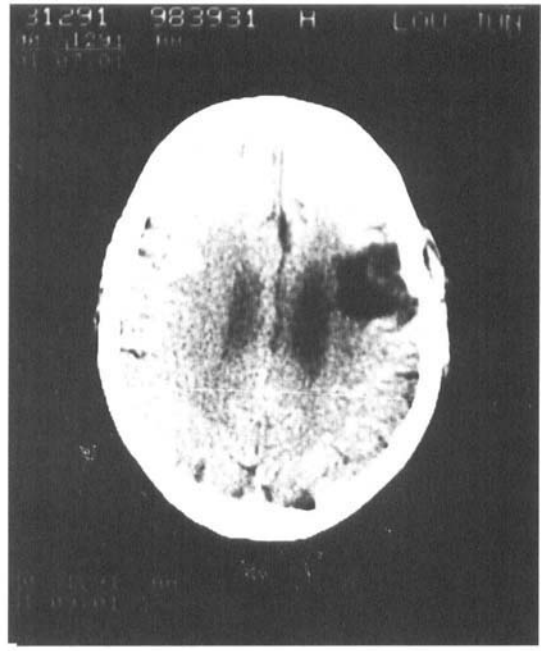
In this study, we report the oral reading of LJG, a Chinese speaker who displays anomia with semantic impairment. We compared LJG's ability to read aloud concrete characters with his ability to generate the same lexical items on a confrontation naming task. We also compared LJG's ability to read aloud concrete characters with his ability to match the same character to a pictorial referent given written word and spoken word input (cf. Hillis and Caramazza, 1991; Graham *et al.*, 1994; Funnell, 1996; Lambon-Ralph *et al.*, 1996). These tasks were carried out in order to test the reliability of the finding that oral reading of concrete characters can remain intact despite impaired access to the mappings between semantic representations and phonological output (cf. Weekes *et al.*, 1997a,b). We then compared LJG's oral reading of regular and irregular Chinese characters matched for written frequency. This test was motivated by the results of Yin (1991) who reported an association between semantic impairment and surface dyslexia in Chinese. Finally, we tested the hypothesis that semantic information constrains the oral reading of irregular Chinese characters by examining the effect of character concreteness on LJG's oral reading of regular and irregular characters. This test was motivated by the results of Howard and Franklin (1988) and Franklin *et al.* (1995) showing that there is an effect of word concreteness on the oral reading of surface dyslexic patients.

Case description

LJG was born in 1940. He is a left-handed male [handedness was assessed with the Chinese version of the Edinburgh Inventory-Reitan Dominance Scale reported by Cheng and Yang (1989)]. LJG is a native speaker of the Putonghua (Mandarin) dialect and was considered to have been a highly literate person in that language. He had completed tertiary studies in Beijing as a young man. LJG was employed as an administrative secretary prior to a cerebrovascular accident (CVA) that occurred in April 1997. A neurological examination conducted at this time found that LJG had a right-sided hemiparesis affecting his right arm and his right leg equally, and no evidence of sensory impairment. A CT scan taken in June 1997 showed evidence of brain damage in the perisylvian region of the left hemisphere and a lesion in the left temporal lobe (shown in Fig. 1).

LJG was seen for broad cognitive assessment in the Department of Rehabilitation Medicine at the China–Japan Friendship Hospital 2 months after the CVA. All testing was conducted in Putonghua by the second author. Spontaneous speech was sparse, non-fluent and simple in content. LJG tended to omit function words (e.g. as, if, but) and occasionally produced neologistic speech output. When given a picture to describe, his speech was perseverative and lacking in content and syntax (e.g. 'He, . . . I cannot . . . one, two, three, . . . literary talent, . . . he is literary talent, . . . literary talent, ohh, big tree, literary talent'). LJG could repeat multisyllabic words and simple sentences, but when asked

(A)



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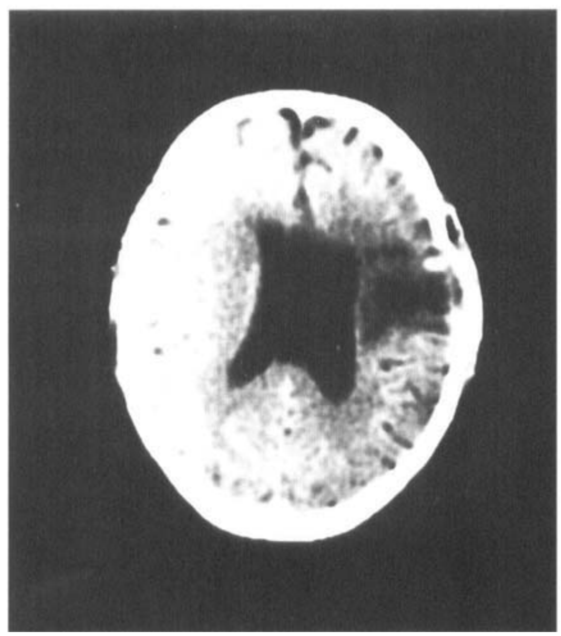

Fig. 1. (A and B) Horizontal sections of a CT scan showing a lesion in the perisylvian region of the left hemisphere.

to repeat complex sentences, such as 'see the rabbit eating the radish', he could repeat only one or two words. On the Raven's Coloured Progressive Matrices (RCPM) test, LJG scored 15/37 and on the Token test he scored 8/150. His performance on both tests is worse than would be expected from a person with his level of education and pre-morbid occupation in China. On subtests of the Chinese version of the Western Aphasia Battery (WAB) which give a possible score of 10, LJG demonstrated impaired performance on tests of spontaneous speech (6), hearing comprehension (4.45), repetition (4.8), naming (3), writing (2.9) and calculation (6.2).

Testing with the Chinese version of the Mini Mental State Examination (Folstein *et al.*, 1975) revealed that LJG could remember his own name and the name of his wife, but he could not recall the names or gender of his children, where he lived, his occupation, his age, the time of day, the day of the week, nor the current month, year or season. However, on a forced choice recognition task, LJG could correctly select his age, occupation and address as well as the names of his children and their gender, suggesting that his apparent memory failures were the result of the expressive aphasia.

Semantic tests

LJG's semantic impairment was evident on a number of tests of naming and comprehension. His performance on all tests was compared to that of two control subjects matched to LJG for age, sex and educational background.

Picture naming

Target stimuli in the picture naming task were 50 line drawings of common objects taken from Snodgrass and Vanderwart (1980). All stimuli were familiar to Chinese speakers according to normative data published by Hua *et al.* (1992). Half of the targets were single-character words and the remainder were two-character words. The line drawings were digitized reproductions printed on white laminated index cards (8 ×16 cm). Each stimulus was presented individually for a maximum of 60 s or until a response was given. LJG named only 20 of the 50 items correctly. Of the 30 errors, 21 (70%) were failures to respond, 6 (20%) were unrelated to the target, e.g. shu(4) *tree* → 'yun(2)' *cloud*, and 3 (10%) were semantically related to the target, e.g. qi(3)e(2) *penguin* → 'bai(2)ge(1)zi' *white pigeon*. LJG's performance was worse than that of controls, who named all items correctly.

Category fluency

When given 60 s to generate as many exemplars as possible, LJG generated the names of only two vegetables (cabbage, squash), one animal (tiger), one bird (crow), three fruit (grape, pear, apple), one item of clothing (shirt), one household utensil (flask), one vehicle (car) and one item of furniture (chair). LJG's performance was sparse compared to control subjects who were able to generate between six (utensils) and 15 (animals) items per category.

Word–picture matching

This task required LJG to point to one of four object pictures in response to a written word or a word spoken by the examiner. In the written word version of the task, LJG was asked to match 50 written words to target pictures and in the spoken word version of the task he was asked to match 50 spoken words to target pictures. The target stimuli were the line drawings used in the picture naming task and the written words were the printed names of those pictures. Half of the stimuli were monosyllabic picture names and half were bisyllabic picture names. Each picture was presented simultaneously with a semantic distractor, a phonological distractor and an unrelated distractor. For bisyllabic targets, the phonological distractor shared one syllable with the target name; for monosyllabic targets, the phonological foil contained the same phonemes as the target, but differed from it in suprasegmental phonology (i.e. tone). Semantic distractors came from the same semantic category as the target, and unrelated distractors had no semantic or phonological similarity to the target. A more detailed description of this task is reported in Weekes *et al.* (1997a). LJG performed half of the written word–picture matching task and half of the spoken word–picture matching task (different target stimuli) in one testing session and the remainder of the two tasks 1 week later.

On the written word version of the task, LJG scored 23/50 (46%) correct (chance equals 25% correct). His errors comprised pointing to phonological distractors (24% of responses), semantic distractors (14% of responses) and unrelated distractors (16% of responses). On the spoken word version of the task, LJG scored 36/50 (72%) correct. Errors were equally likely to be phonological or semantic distractors (14% of responses) and he never chose an unrelated distractor. LJG's performance on both versions of the task was better than chance, indicating that he understood the task requirements. However, his performance was worse than control subjects who performed with 100% accuracy on both versions of the task.

Lexical decision

LJG was given a test of lexical decision with 20 single-character words and 20 pseudocharacters printed on plain white laminated index cards (8 × 16 cm). Pseudocharacters were formed by combining a component from one character with a component from another character to create a stimulus that resembled a Chinese character, but had no meaning in Chinese. LJG was asked to indicate whether he recognized each stimulus as a word (yes) or not a word (no). LJG had a hit rate of 1.0, but a false-positive rate of 0.50. This gives a $d' = 2.32$, which is well above chance but below normal performance.

Table 1. Comparisons between LJG's performance on oral reading, picture naming and word–picture matching tasks

		Picture naming		Written-word–picture matching		Spoken-word–picture matching	
		√	X	√	X	√	X
Oral reading	√	17	25	18	24	31	11
	X	3	5	5	3	5	3

Reading aloud

Oral reading task 1

The target stimuli in oral reading task 1 were the printed names of the line drawings used in the picture naming task (and therefore also the target words used in the word–picture matching task). All stimuli were concrete words. LJG was asked to read aloud 50 Chinese words. Stimuli were printed on plain white laminated index cards (8 × 16 cm). Each stimulus was presented individually for a maximum of 60 s or until a response was given. LJG read 42/50 (84%) of the characters correctly. His errors included one semantic error; two one-character-correct errors defined as a response where one syllable of a multisyllabic name was produced correctly, e.g. 摇椅 'yao(2)yi(3)' *rocking chair* → 摇扇 'yao(2)shan(4)' *fan*; two addition errors defined as a response where the target was pronounced correctly, but a redundant syllable was added 梳 *comb* 'shu(1)' → 梳子 *comb* 'shu(1)zi'; and two failures to respond. LJG also made one LARC error whereby the word 豹 'bao(4)' *leopard* was pronounced 'shao(2)' *ladle*, which is the correct name of the component 勺 'shao(2)' scoop.

LJG's performance on oral reading task 1 was compared to his performance on the picture naming task; the written-word/picture matching task and the spoken-word/picture matching task. The results are summarized in Table 1. According to McNemar's test, LJG's oral reading performance was significantly better than his picture naming performance ($\chi^2(1) = 22.00$, $P < 0.001$), written-word/picture matching performance ($\chi^2(1) = 19.00$, $P < 0.001$) and spoken-word/picture matching performance ($\chi^2(1) = 6.00$, $P < 0.001$). Thus, despite LJG's impairments on tests of naming and comprehension, he displays relatively well-preserved oral reading of many concrete lexical items that he fails to name or to comprehend correctly.

Oral reading task 2

LJG was asked to read aloud 120 printed monosyllabic Chinese words. All words were compound characters defined according to the criterion that the character was composed of at least two separable components (cf. Leck *et al.*, 1995). All stimuli are reported in the Appendix. Half the characters were regular characters and half were irregular characters. We defined character regularity in the following way. If the name of any one character component, e.g. 青 'qing(1)', had the same name as the character as a whole, then we called this stimulus a regular character, e.g. 清 'qing(1)' which means *clean*. However, if no character component had the same name as the character, then we called this stimulus an irregular character, e.g. 猜 'cai(1)' which means *guess*.

Half of the stimuli were concrete characters and half were abstract characters. Concrete characters were defined according to the criterion that the stimulus had a sensory referent. All character stimuli had been classified as concrete or abstract by 20 students prior to testing with LJG. We varied written character frequency in three bands: high, medium and low frequency. In order to estimate character frequency, we used a Dictionary of Chinese Character information called the *Hanzi Xinxi Zidian* (1988), which gives information about the token frequency of characters and character components in written Chinese. High-frequency stimuli had a frequency greater than 79 occurrences per million, mid-frequency stimuli had a frequency of between 15 and 79 occurrences per million and low-frequency stimuli had a frequency of less than 15 occurrences per million. There were no significant differences in mean written frequency between abstract–regular, abstract–irregular, concrete–regular and concrete–irregular stimuli within the three frequency bands (all $F < 1$).

Stimuli were individually printed on plain white laminated index cards (8 × 16 cm) and presented for a maximum of 60 s or until a response was given. All responses were recorded manually by a Mandarin speaker (the second author). LJG's oral reading performance and that of two control subjects is presented in Fig. 2.

ANOVA found significant effects of character regularity ($F(1,9) = 12.25$, $P < 0.01$), concreteness ($F(1,9) = 17.05$, $P < 0.01$) and frequency ($F(1,9) = 9.94$, $P < 0.01$) on LJG's oral reading performance, but there were no effects of character regularity, concreteness or frequency on the oral reading of controls. LJG made more errors when reading aloud irregular words compared to regular words ($t(9) = 3.5$, $P < 0.01$), more errors when reading aloud abstract words compared to concrete words ($t(9) = 4.9$, $P < 0.01$), and more errors when reading aloud low-frequency words compared to high-frequency words ($t(9) = 2.5$, $P < 0.05$) and medium-frequency words ($t(9) = 4.2$, $P < 0.01$). The difference between high- and medium-frequency words was not significant ($t < 1$). The effect of concreteness on LJG's oral reading was qualified by a significant two-way interaction between regularity and concreteness ($F(2,9) = 7.59$,

Table 2. Errors made by LJG to stimuli in the irregular, low-frequency, abstract character condition

LARC	诅 →	且	抨 →	平	祈 →	斤	烁 →	乐	眠 →	民
	zu(3) *curse*	'ju(3)' *chew*	peng(1) *attack*	'ping(2)' *flat*	qi(2) *pray*	'jin(1)' *weight*	shuo(4) *bright*	'yue(4)' *music*	mian(2) *sleep*	'min(2)' *people*
Semantic	坍 →	墙								
	tan(1) *collapse*	'qiang(2)' *wall*								

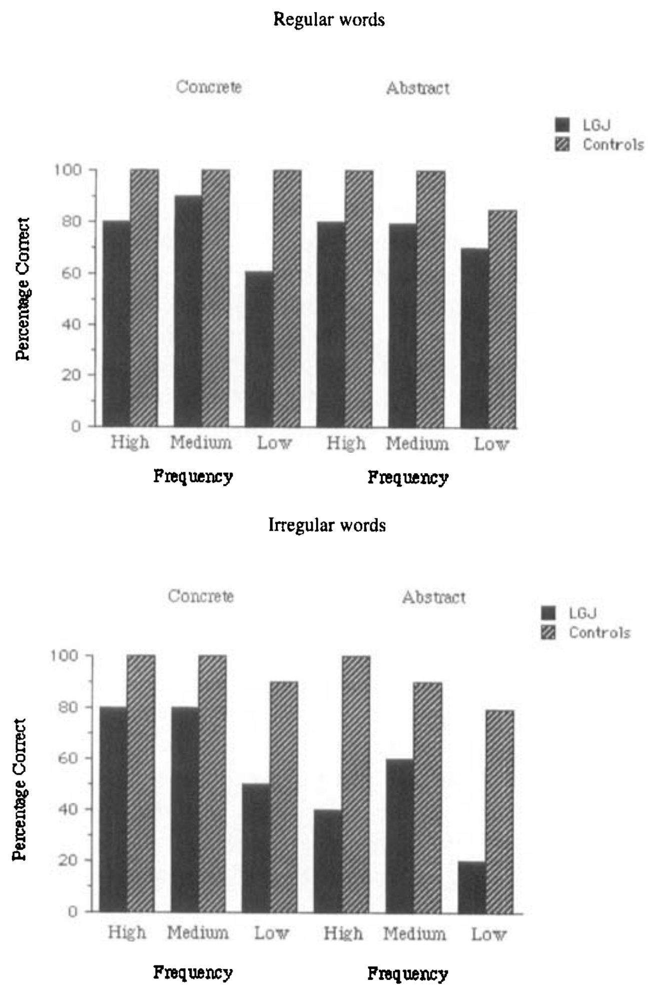

Fig. 2. Percentage of regular and irregular words read correctly by LJG and control subjects.

$P < 0.01$). LJG made more errors with irregular abstract words compared with irregular concrete words ($t(9) = 3.3$, $P < 0.01$), but there was no significant difference between his reading of regular abstract and regular concrete words ($t < 1$). Figure 2 shows that LJG made the largest number of errors when reading aloud irregular, abstract characters with an average frequency of less than 15 occurrences per million.

LJG's oral reading errors could be classified into one of three types: LARC errors, semantic errors and unrelated errors. Examples of LJG's oral reading errors from the irregular, low-frequency abstract word condition are reported in Table 2.

A summary of LJG's oral reading errors is reported in Table 3. In the irregular character conditions, LJG made nine LARC errors in total (15% of responses) and he made at least one LARC error in each irregular character condition. The only exception to this was the irregular, high-frequency, concrete character condition in which he did not make any LARC errors. Table 3 also shows that LARC errors became more prevalent as character frequency decreased, although LARC errors were not confined to low-frequency characters.

A comparison of the mean written frequency of the components that LJG read aloud in error and the mean written frequency of the irregular character containing that component revealed a highly significant difference ($t(8) = 345.67$, $P < 0.0001$). In all cases, the mean written frequency of the component was greater than the mean written frequency of the character itself. Thus, when LJG produced an LARC error, it was always of higher frequency than the target. Control subjects also produced a small number of LARC responses when reading aloud irregular low-frequency, abstract characters (e.g. 抨 peng(1) read as 'ping(2)' which is the correct pronunciation of the component 平; 呷 xia(1) read as 'jia(3)' which is the correct pronounciation of the component 甲;烁 shuo(4) read as 'le(4)' which is the correct pronounciation of the component 乐).

Discussion

LJG displays well-preserved oral reading of concrete Chinese characters in the context of impaired naming of the same lexical items from pictorial input. The pattern of impaired naming co-incident with well-preserved oral reading of concrete characters is similar to the pattern of oral reading performance displayed by patient YQS reported by Weekes *et al.* (1997a). Thus, LJG's pattern of well-preserved oral reading of concrete characters provides converging evidence that the oral reading of concrete characters can proceed despite impaired access to the mappings between semantic representations and phonological output. LJG also displays relatively well-preserved oral reading of concrete characters in the context of impaired comprehension of the same lexical items from written word and from spoken word input. This finding is compatible with reports of intact oral reading of English words by patients who have semantic impairment

Table 3. Numbers of various reading error types made by LJG in oral reading task 2

	Regular						Irregular					
	Concrete			Abstract			Concrete			Abstract		
	HF	MF	LF	HF	MF	LF	HF	MF	LF	HF	MF	LF
LARC	0	0	0	0	0	0	0	1	1	1	1	5
Semantic	0	0	1	0	0	0	0	0	0	0	0	1
Unrelated	2	0	0	1	1	0	1	1	3	5	3	0
DK	0	1	3	1	1	3	1	0	1	0	0	2
Total	2	1	4	2	2	3	2	2	5	6	4	8

(Bayles, 1982; Friedman *et al.*, 1992) and reports of intact oral reading of Kanji characters by Japanese speakers who have semantic impairment (Sasanuma *et al.*, 1992).

The Weekes *et al.* (1997a) framework can account for LJG's intact oral reading of concrete characters that he cannot comprehend or name from pictorial input as the result of reading via a direct pathway. However, even though LJG's oral reading of concrete characters is relatively well preserved, he displays a pattern of surface dyslexic reading that is similar to the pattern reported by Yin (1991) and Yin and Butterworth (1992). Like those patients, LJG displays a tendency to produce LARC errors when reading aloud irregular Chinese characters, and this tendency becomes more pronounced as word frequency declines. The effect of word frequency on irregular word reading displayed by LJG is compatible with studies of the oral reading of normal Chinese speakers (e.g. Seidenberg, 1985; Fang *et al.*, 1986; Hue, 1992). These studies have found that low-frequency irregular characters are the most prone to error under time pressure for normal Chinese readers. The effects of word frequency on LJG's irregular word reading are also consistent with the pattern of impaired oral reading of irregular words by English-speaking surface dyslexic patients (Bub *et al.*, 1985) and the reading of Japanese surface alexic patients (Patterson *et al.*, 1995).

Yin (1991) and Yin and Butterworth (1992) argued that Chinese patients who make LARC errors use shallow 'sublexical' connections between orthographic representations and phonological output that are available to normal Chinese readers. However, the issue of whether Chinese character components have any special status in the mapping process between orthographic representations and phonological output is controversial. This is because phonetic radical components are Chinese characters in their own right with their own pronunciations as well as their own meanings. Thus, putative sublexical processing of radicals may be a lexical event at the semantic and phonological levels (cf. Zhou and Marslen-Wilson, 1997). We therefore reject the notion that LJG's impaired oral reading reflects the use of a sublexical reading pathway.

We propose that LJG's impaired oral reading simply reflects the cognitive processes involved in the normal oral reading of irregular Chinese characters. We begin our account of LJG's oral reading with the assumption that when a normal reader pronounces a monosyllabic or a multisyllabic Chinese word, the process of computing phonology from orthography occurs at multiple levels (cf. Shallice *et al.*, 1983; Shallice and McCarthy, 1985; Shallice, 1988). In Chinese, these levels include the component (radical) level, the character level and the whole-word level itself (which can be made up of either monosyllabic or multisyllabic units). These levels of translation compete or co-operate with each other and eventually result in the fluent pronunciation of a Chinese word (see also Taft and Zhu, 1995).

Zhou and Marslen-Wilson (1997) have argued that the process of reading aloud an irregular Chinese character is different to the process of reading a regular Chinese character. For regular characters, the computation of phonological output from character components will activate the same representations as the whole character itself. Therefore, when a regular character is read aloud, there will be no competition between alternative phonological forms for response output. However, when irregular Chinese characters are read aloud, the computation of phonological output from character components will activate a competing phonological representation. This is because irregular characters contain components that have different pronunciations to the whole character itself. Therefore, when an irregular character is read aloud, the stimulus will generate more than one response alternative. This will naturally lead to competition between different phonological forms for response output during normal oral reading.

In order for the correct pronunciation of an irregular Chinese character to be read aloud, some response criterion will be required. This criterion will be used to determine which of several possible phonological forms will be selected as the correct pronunciation, while competing alternatives are inhibited. Response competition for the correct pronunciation of an irregular Chinese character will become greater as word frequency declines. This is because character components are more likely to have a lower threshold for response than the pronunciation of the whole character itself. One reason for this is that the written frequency of the components that make up a low-frequency Chinese character can themselves have a relatively high token frequency in the script (Zhou and Marslen-Wilson, 1997). Therefore the frequency of the components in a Chinese character can be higher than the token frequency of the character itself.

Thus far, we have offered an account of why irregular word oral reading might be more prone to error than regular word oral reading in Chinese. However, Chinese speakers can read aloud low-frequency irregular Chinese characters without error and, moreover, they do not make LARC errors as a matter of course in normal oral reading (although LARC errors can be produced by control subjects). Thus, we still need to account for why LJG's oral reading of irregular words is impaired and why he tends to make a relatively large number of LARC errors when reading these stimuli aloud.

According to the Weekes *et al.* (1997a) framework, there are a number of levels of representation within the direct reading pathway that, if damaged following brain damage, could result in impaired oral reading. These include orthographic units at the level of stroke, radical or character representations and phonological units at the level of syllabic, phoneme or tone representations. LJG's above chance performance on the lexical decision task indicates that orthographic representations are largely intact and can sustain a high level of performance on word recognition tasks (including oral reading). There was no evidence of impairment at the level of tone or phoneme production on tests of LJG's oral reading or confrontation naming, suggesting that phonological units are also intact. There was, however, evidence of phonological underactivation on tests of confrontation naming, category fluency and oral repetition, as well as on tests of spoken word comprehension affecting both monosyllabic and multisyllabic words. We submit that LJG's impaired oral reading of irregular words results from a failure to inhibit competing response alternatives that have a lower threshold level for pronunciation. LJG's tendency to produce LARC errors when reading aloud irregular characters follows naturally from this interpretation. This is because a LARC error is simply a competing response alternative. We have shown that the names of the character components that LJG produces in error are of higher written frequency (and therefore have a lower threshold level for pronunciation) than the target names themselves. This confirms to us that one cause of LJG's surface dyslexia is a failure to inhibit competing response alternatives that have a lower threshold for pronunciation during the oral reading of irregular Chinese characters.

LJG's surface dyslexia is most evident when reading aloud abstract, irregular characters that have a low frequency of occurrence in written Chinese. Our finding is compatible with the results of Howard and Franklin (1988) and Franklin *et al.* (1995), who found that abstract, irregular words were the most prone to error for English-speaking surface dyslexic patients who have semantic impairment. The finding that character concreteness has an effect on LJG's oral reading of irregular characters is direct evidence in favour of the hypothesis that semantic information constrains the oral reading of irregular Chinese characters. Our finding is compatible with the results of Strain *et al.* (1995) showing interactive effects of word concreteness and regularity on the normal oral reading of English words. We note, however, that word concreteness does not invariably affect the oral reading of irregular words by patients with semantic impairment (e.g. Coslett, 1991; Sasanuma *et al.*, 1992; Raymer and Berndt, 1994).

One reason for the effect of concreteness on LJG's oral reading may be that abstract characters have less consistent semantic representations than concrete characters and will therefore provide less activation of their corresponding phonological representations (cf. Plaut and Shallice, 1993; Breedin *et al.*, 1994). If a patient has semantic impairment or impairment to the mappings between semantic representations and phonological output, abstract word oral reading will be more prone to error because abstract characters provide less activation of phonological representations. This account can be extended to explain the interaction between character concreteness and character regularity on LJG's oral reading if it is assumed that his impaired oral reading of abstract, irregular characters reflects the underactivation of phonological units of representation.

Patterson and Hodges (1992) argued that successful oral reading of low-frequency irregular words of English is parasitic upon access to word meaning (see also Patterson *et al.*, 1994; Plaut *et al.*, 1996). According to the Patterson and Hodges' (1992) hypothesis, there is a mechanism which directly computes phonology from orthography during normal oral reading. This direct computation is capable of reliably translating print to phonology for all words with regular spellings and can also convert more frequently encountered irregular words from print to sound. However, in the case of less common irregular words, the direct mapping process requires support from the semantic representations of those words if they are to be pronounced correctly. One reason for this is that low-frequency words with atypical pronunciations of one or more of their orthographic components will take longer to reach a stable pattern of phonological activation. Take as an example the computation from orthography to phonology of the low-frequency irregular word PINT. This letter string will activate both the vowel /aɪ/, which is correct, and the vowel /ɪ/, which is incorrect, but much more typical of words with similar orthographic patterns such as MINT and PINK. The Patterson and Hodges (1992) hypothesis assumes that the correct phonological representation p/aɪ/nt receives additional activation from semantic memory and this is why the correct alternative is the one that is generated in normal oral reading. Without semantic support to help the system settle on the correct but atypical pronunciation, alternative and usually more typical pronunciations of the components of a word will dominate the computation from orthography to phonology. Note here that it makes little difference to the Patterson and Hodges (1992) theory whether lack of semantic support is due to disrupted semantic representations or impairment to the mappings between semantic representations and phonological output.

The Patterson and Hodges (1992) hypothesis was originally proposed to account for the reported association between semantic impairment and the tendency to regularize low-frequency irregular words of English (see also Funnell, 1996). However, Patterson *et al.* (1995) argued that the results of testing with NK lent support to the principle that underactivated phonological representations will be vulnerable to a lack of semantic support. The results of testing with LJG show clearly that a patient who has anomia with semantic impairment gives pronunciations associated with the components of an irregular character rather than the pronunciation of the character itself. As such, LJG's pattern of results extends the principle that underactivated phonological representations will be vulnerable to a lack of semantic support to the case of oral reading in Chinese.

In conclusion, the results of testing with LJG have yielded a number of findings that are of relevance to our understanding of oral reading in Chinese. We have shown that oral reading of concrete characters can remain relatively well preserved despite impaired naming and comprehension of the same lexical items. However, our results also show that there is an association between semantic impairment and surface dyslexia in Chinese. LJG's tendency to misread low-frequency, irregular characters could be seen simply as a consequence of the general vulnerability of whole-word phonological representations to brain damage (cf. Shallice *et al.*, 1983; Shallice and McCarthy, 1985; Shallice, 1988). However, we have argued that the oral reading of irregular Chinese characters is more prone to error than the oral reading of regular Chinese characters because of response competition for the pronunciation of an irregular character at the level of phonological output. For LJG, this tendency is directly related to his impaired oral reading of characters that have abstract semantic meanings. This, in turn, implies that semantics is normally used to resolve response competition for the pronunciation of an irregular Chinese character and, when semantics is impaired, a pattern of surface dyslexia will emerge.

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Appendix

Regular concrete

high frequency

芽	秧	枝	油	房	柱	钟	珠	锤	箱
ya2	yang1	zhi1	you2	fang2	zhu4	zhong1	zhu1	chui2	xiang1
bud	sprout	branch	oil	house	post	bell	bead	hammer	box

medium frequency

舰	肤	秆	饵	砖	肝	蚊	铃	肢	蚜
jian4	fu1	gan3	er3	zhuan1	gan1	wen2	ling2	zhi1	ya2
warship	skin	stalk	bait	brick	liver	mosquito	bell	limb	aphid

low frequency

杖	鸠	衫	鸦	蚂	狸	杈	虾	蚁	蚪
zhang4	jiu1	shan1	ya1	ma3	li3	cha1	xia1	yi3	dou3
cane	turtledove	shirt	crow	ant	fox	hayfork	lobster	ant	tadpole

Regular abstract

high frequency

极	拥	味	注	响	胜	政	态	换	样
ji2	yong1	wei4	zhu4	xiang3	sheng4	zheng4	tai4	huan4	yang4
extreme	embrace	taste	pour	sound	success	politics	appearance	change	sample

medium frequency

玛	扶	拒	抖	邻	冻	汪	抹	驶	炸
ma3	fu2	ju4	dou3	lin2	dong4	wang1	mo3	shi3	zha4
agate	support	refuse	tremble	neighbour	freeze	vast	wipe	drive	explode

low frequency

沐	忧	诈	诽	抿	枉	咏	绅	哑	炳
mu4	you1	zha4	fei3	min3	wang3	yong3	shen1	ya3	bing3
bathe	anxiety	cheat	slander	sip	wrong	singing	gentry	dumb	bright

Irregular concrete

high frequency

灯	枪	刺	矿	炉	星	缸	袖	眼	剪
deng1	qiang1	ci4	kuang4	lu2	xing1	gang1	xiu4	yan3	jian3
lamp	gun	dagger	mine	stove	star	vat	sleeve	eye	scissors

medium frequency

肚	鸡	杯	肺	酒	桃	鸭	钳	狼	肠
du4	ji1	bei1	fei4	jiu3	tao2	ya1	qian2	lang2	chang2
belly	chicken	cup	lung	wine	peach	duck	pincers	wolf	intestines

low frequency

肘	驴	袜	坟	虹	裙	钵	秤	梳	蚌
zhou3	lu2	wa4	fen2	hong2	qun2	bo2	cheng4	shu1	bang4
elbow	ass	socks	tomb	rainbow	skirt	bowl	steelyard	comb	clam

Irregular abstract

high frequency

坏	规	浅	怕	细	研	残	独	祖	徒
huai4	gui1	qian3	pa4	xi4	yan2	can2	du2	zu3	tu2
bad	regulation	shallow	afraid	thin	study	remaining	single	ancestor	merely

medium frequency

扰	狂	诉	欣	泄	孤	狠	秒	陡	祥
rao3	kuang2	su4	xin1	xie4	gu1	hen3	miao3	dou3	xiang2
harass	crazy	inform	glad	release	lone	ruthless	second	steep	good

medium frequency

坍	诅	拓	抨	呷	氓	祈	烁	眠	畔
tan1	zu3	tuo4	peng1	xia1	mang2	qi2	shuo4	mian2	pan4
collapse	curse	develop	denounce	sip	rogue	pray	bright	sleep	bank

Surface dyslexia in Chinese

B. Weekes and H. Q. Chen

Abstract
We report the oral reading performance of a Chinese anomic patient LJG, whose reduced confrontation naming was accompanied by impaired written word and spoken word comprehension. LJG's oral reading is significantly better than his comprehension of the same lexical items from written word and from spoken word input, although his oral reading is not flawless. We examined the effects of character regularity, frequency and concreteness on LJG's oral reading of single-character monosyllabic Chinese words. LJG displayed impairment when reading aloud irregular Chinese characters that have an unpredictable correspondence between their components and the pronunciation of the character as a whole. This deficit was particularly severe for irregular, low-frequency, abstract items. In addition, LJG produced a number of oral reading errors in which characters were assigned pronunciations appropriate to a character component rather than the character itself. We characterize LJG's oral reading as surface dyslexia. We argue that the oral reading of irregular Chinese characters is more prone to error than oral reading of regular Chinese characters following brain damage because of response competition at the level of phonological output.

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Primary diagnosis of interest
Surface dyslexia

Author's designation of case
LJG

Key theoretical issue
- The relationship between semantic impairment and acquired surface dyslexia
- Models of oral reading

Key words: Chinese characters; anomia; surface dyslexia; semantic impairment

Scan, EEG and related measures
CT scan

Standardized assessment
RCPM
MMSE (Chinese version)
Token Test (Chinese version)
Western Aphasia Battery (Chinese version)
Edinburgh Inventory-Reitan Dominance Scale (Chinese version)

Other assessment
Detailed assessment of reading and speech comprehension and reading aloud

Lesion location
- Left perisylvian region

Lesion type
Cerebrovascular accident

Language
Chinese