

# Semantic errors in deep dyslexia: Does orthographic depth matter?

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Semantic errors of oral reading by aphasic patients are said to be comparatively rare in languages with a shallow orthography. The present report concerns three bilingual brain-damaged patients who prior to their stroke were fluent in both English, an orthographically deep language, and Welsh, an orthographically shallow language. On a picture-naming task, each patient made a similar proportion of semantic errors in the two languages. Similarly, in oral reading of the corresponding words, no patient produced proportionally more semantic paralexias in English than in Welsh. The findings are discussed in relation to the summation hypothesis as invoked by Miceli, Capasso, and Caramazza (1994) to explain apparent differences in frequency of semantic errors of reading in languages differing in orthographic depth.

Deep dyslexia is an acquired disorder of oral reading observed in brain-damaged patients, especially Broca's aphasics with large lesions of the left hemisphere (for anatomical review see Lambon Ralph & Graham, 2000). Semantic errors in reading aloud (semantic paralexias) constitute the cardinal symptom of deep dyslexia (Coltheart, 1980, 2000).

In some languages, such as English, the relationship between orthography and phonology is not one-to-one. A given letter string can be pronounced in different ways (for example, the different pronunciations of *wind* or *tear*). Conversely, a given sound can be represented in different ways (such as the "ee" sound in *bead* or *freed*). The orthography of English and of other languages with similar inconsistency in letter-sound

relationships is said to be deep or opaque. In shallow or transparent orthographies such as Turkish, German, Spanish, and Italian, the letter-sound relationships are more regular and consistent.

The Welsh orthography is highly transparent (Fear, 1997; Spencer & Hanley, 2003). Welsh is spoken as a first language in Wales by about 19% of the population over the age of 20 (Welsh Language Board, personal communication) but all Welsh speakers also learn English. This means that they grow up reading one orthographically shallow language (Welsh) and another orthographically deep language (English).

Reports of deep dyslexia/dysgraphia in a shallow language are relatively rare (see below). This may be because semantic errors of reading

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occur infrequently in orthographically shallow languages (see Ferreres & Miravalles, 1995) and/or because they are, for whatever reason, reported relatively infrequently (for review of studies of deep dyslexia in Spanish see Davies & Cuetos, 2005). Discussions concerning the relative frequency of occurrence of semantic errors of reading in deep and shallow orthographies have been very largely based upon comparisons between monolingual brain-damaged readers of these orthographies.

Two papers often cited in relation to the apparent rarity of semantic errors in Spanish and Italian are those by Ardila (1991) and Basso and Corno (1994), respectively. Ardila (1991) reported that no semantic errors were made by any of 41 monolingual Spanish-speaking aphasics who were given tests of reading that included a list of 13 single words. Basso and Corno (1994) retrospectively examined the records of 502 brain-damaged Italian patients who were each given a reading test consisting of 10 words. The number of semantic errors was very low. However, deep dyslexic patients do not make errors on every experimental trial. Consequently, 10–13 is too low a number of trials with which to elicit a reasonable number of semantic paralexias. Indeed, Basso and Corno (1994) begin their discussion by acknowledging that “The small number of stimuli in our test precludes any possibility of making a diagnosis of deep dyslexia” (p. 154).

An alternative approach to evaluating the role of orthographic depth in the production of semantic paralexias can be made by comparing oral reading performance of deep dyslexic patients who are fluent readers of both an orthographically deep and an orthographically shallow language. There are, however, relatively few studies of acquired reading disorders in bilingual (biscrptal) readers (Paradis, 1994; Ratnavalli et al., 2000). The first published investigation of a bilingual deep dyslexic person appears to be that of Byng, Coltheart, Masterson, Prior, and Riddoch (1984); the patient was deep dyslexic in English while reading was said to be almost impossible in the (syllabic) Devanagari script. More recently, B eland and Mimouni (2001) tested an Arabic/

French bilingual patient, Z.T. This patient was reported to be deep dyslexic in both French and (deep) Arabic but to show more semantic errors in French. Karanth (2002) reported on a bilingual English–Hindi speaking aphasic patient who showed the pattern of deep dyslexia in English but made no semantic errors in Hindi, described as having “high gpc [grapheme–phoneme correspondence]” and “nearly always regular” (p. 144). Reading was said to be poorer overall in Hindi but no quantitative data are provided—perhaps there was insufficient opportunity for semantic errors to arise in Hindi. Raman and Weekes (2005) report the case of a bilingual Turkish–English reader who was deep dysphasic (that is, made semantic errors of repetition) but surface dyslexic in both languages (though when presented with Turkish words to read some of his responses were semantic errors given in English).

Miceli, Capasso, and Caramazza (1994) attempted to account for the apparent difference in frequency of semantic errors in oral reading between readers of opaque and transparent orthographies in terms of the summation hypothesis (Caramazza & Hillis, 1990; Hillis & Caramazza, 1991; Miceli, Capasso, & Caramazza, 1999). According to this hypothesis, semantic errors in deep dyslexia are considered to arise if the response from the semantic-lexical route is insufficiently constrained by information from the sublexical route. Miceli et al. (1994) suggest that in orthographically transparent languages these two sources of information are more or less identical. By contrast, in an orthographically deep or opaque language, such as English, the two sources of information will on occasion conflict. For example, the word *yacht* may be pronounced in one of two ways (*yot* versus *y t* [ʃt]) depending on whether it is read as a whole word or decomposed using grapheme–phoneme conversion rules. Damage to a sublexical conversion route would be expected to limit the ability of this route to contribute to correct reading aloud. Miceli et al. (1994) argue that “the same cognitive damage to sublexical conversion mechanisms in a language with transparent and in one with opaque orthography might result in *vastly* [italics added] different consequences in

reading and writing performance: in opaque languages, it could lead to a severe functional deficit of sublexical conversion; whereas in transparent languages it would interfere only minimally with sublexical conversion. Thus in a language with opaque orthography, damage to a sublexical conversion procedure would result in a situation where the output of the damaged component would consist of relatively unusable information in constraining the activation of lexical entries in the relevant output lexicon. By contrast, in a language with transparent orthography the comparable amount of damage to a sublexical conversion procedure would have relatively minor effects on the information value of the output of the damaged process, at least with respect to its role in constraining the activation of lexical forms in the relevant output lexicon. The obvious consequences of these contrasting situations is that transparent orthography languages are relatively “protected” from the production of semantic paralexias and paraphasias because the sublexical conversion mechanisms even when damaged continue to provide information that is useful in constraining the activation of phonological and orthographic lexical forms” (p. 331).

A clear prediction from the argument put forward by Miceli et al. (1994) is that a bilingual English–Welsh deep dyslexic patient will make proportionally more semantic errors in oral reading of English (orthographically deep) than of Welsh (orthographically shallow) words. There should not, however, be any difference between the two languages in the frequency of semantic errors made in picture naming since this task does not engage the sublexical reading route, which therefore cannot contribute to the patient’s performance. This paper reports a test of these predictions.

## Method

### *Participants*

Three bilingual patients were each tested from 5 to 6 years after a left-sided cerebrovascular accident (CVA), at which time their medical condition and cognitive status were stable. Although fluent

speakers and readers of English and Welsh prior to their stroke, two of the patients (P.D. and J.W.T.) considered English to be their dominant language while the third (M.J.) considered Welsh to be her dominant language. Poststroke all three patients were dysphasic. Speech was effortful and dysfluent with some difficulty in articulation. Aphasia quotients as determined by the Western Aphasia Battery (WAB; Kertesz, 1982) are given below for each patient. There is no comparable aphasia battery for use with Welsh-speaking patients.

Patient P.D., male, aged 50 at the time of testing, suffered a left CVA in July, 2000. Computed tomography (CT) scan shortly after admission to hospital showed a large area of infarction in the territory of the left middle cerebral artery (Figure 1). His WAB aphasia quotient was 36.

Patient J.W.T., male, aged 69 at the time of testing, suffered a left CVA in June 1998. CT scan (Figure 2) on the day of admission revealed a moderately sized area of infarction involving the left parietal region (left middle cerebral artery territory). According to the radiologist’s report: “There was also another smaller area of infarction at the right posterior parietal region—the latter maybe an old one. No other focal endocranial lesions or midline shift.” WAB aphasia quotient was 40. J.W.T. died suddenly on the 20th July 2006.



Figure 1. CT scan for P.D. (male, 50 years old).



Figure 2. CT scan for J.W.T. (male, 69 years old).

Patient M.J., female, aged 71 at the time of testing suffered a left CVA in September 1999. CT scan (Figure 3) two days after her stroke showed a small left parietal infarct. WAB aphasia quotient was 64. M.J. died in January, 2006.

#### Procedure

Each participant was given a number of background assessment tests over a series of sessions. These included the Western Aphasia Battery (Kertesz, 1982) and a number of subtests from the



Figure 3. CT scan for M.J. (female, 71 years old).

Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) battery (Kay, Lesser, & Coltheart, 1992). Some of the PALPA tests were adapted for testing in Welsh, usually by translating the English word into Welsh. Occasionally, however, the Welsh word was different in length to the English equivalent, in which case a Welsh word of the same number of syllables and of approximately equivalent familiarity and imageability (see Fear, 1997) was substituted. There are no irregularly spelled words in Welsh so all Welsh words were regular. Nonwords were devised so as to be equivalent to the corresponding English nonwords. Note, incidentally, that the Welsh alphabet is not exactly the same as the English alphabet. For example, there is no English equivalent of the Welsh “ll”, and there is no “k” in the Welsh alphabet; the Welsh letter “f” is pronounced as a “v” in English; the Welsh “ff” is pronounced as English “f”.

The stimulus items for picture naming and oral reading were taken from the Snodgrass and Vanderwart (1980) set. Dual-word items (such as “lamp shade” and “light bulb”) were removed from the stimulus set prior to administration of the tasks. Pictures that had a name agreement in English of less than 60% according to Bates et al. (2003) were also removed, leaving 222 items from the Snodgrass and Vanderwart (1980) set. These 222 items were shown to a panel of 18 native Welsh speakers who were asked to provide the Welsh name for each item. Name agreement was greater than 70% for all items. These stimuli were subsequently presented one at a time to each of our three patients who was asked to provide its name in English or in Welsh or to read the corresponding English or Welsh word depending upon condition.

The stimuli were presented in pseudorandom order to each patient across a number of sessions, with the constraint that the same item was not presented for reading and naming within the same session. Within each session, items were blocked according to language of response. That is, participants responded to a set of items in English only or in Welsh only throughout a

Table 1. *WAB aphasia scores*

<i>WAB subtest</i>	<i>Scores</i>		
	<i>P.D.</i>	<i>J.W.T</i>	<i>M.J.</i>
Spontaneous speech			
(a) Information content	5 (10)	4 (10)	8 (10)
(b) Fluency	2 (10)	2 (10)	6 (10)
Comprehension			
(a) Auditory verbal comprehension	51 (60)	57 (60)	54 (60)
(b) Auditory word recognition	45 (60)	55 (60)	54 (60)
(c) Sequential commands	11 (80)	40 (80)	50 (80)
Repetition	17 (100)	24 (100)	44 (100)
Object naming	26 (60)	27 (60)	36 (60)
(a) Word fluency	1 (20)	5 (20)	5 (20)
(b) Sentence completion	2 (10)	6 (10)	8 (10)
(c) Responsive speech	4 (10)	5 (10)	8 (10)
Reading			
(a) Reading comprehension	14 (40)	22 (40)	22 (40)
(b) Reading commands	6 (20)	8 (20)	8 (20)
(c) Written word–object matching	6 (6)	6 (6)	6 (6)
(d) Written word–picture matching	6 (6)	6 (6)	6 (6)
(e) Picture stimuli–word matching	6 (6)	6 (6)	6 (6)
(f) Spoken word–visual word match	3 (4)	4 (4)	3 (4)
(g) Spoken word–visual letter name	4 (6)	5 (6)	5 (6)
(h) Oral spelling (by examiner: patient says word spelled)	0 (6)	1 (6)	1 (6)
Spelling	0 (6)	0 (6)	2 (6)
Writing			
(a) On request (e.g., name & address)	3 (6)	4 (6)	3 (6)
(b) Written output from pics stimuli	1 (34)	0 (34)	6 (34)
(c) Writing to dictation	0 (10)	2 (10)	2 (10)
(d) Writing words from visual stimuli	0 (10)	2 (10)	4 (10)
(e) Writing the alphabet	4 (12.5)	6 (12.5)	9 (12.5)
(f) Writing numbers 0–20	10 (10)	10 (10)	9.5 (10)
(g) Dictated letter names	1 (2.5)	2 (2.5)	2 (2.5)
(h) Dictated numbers	2 (5)	4 (5)	4 (5)
(i) Copying a sentence from a card	8 (10)	7 (10)	8 (10)
Apraxia: Carrying out oral commands	40 (60)	60 (60)	60 (60)
Constructional and calculation			
(a) Construction: drawing	10 (30)	14.5(30)	—
(b) Calculation	16 (24)	24 (24)	

*Note:* WAB = Western Aphasia Battery. Maximum score in parentheses.

session. If the patient gave the plural rather than singular form of a stimulus item it was accepted as correct.

## Results

The patients' scores on subtests of the Western Aphasia Battery are shown in Table 1, and their

scores on PALPA and other tests are shown in Table 2.

Patients P.D. and J.W.T. showed an effect of imageability in reading words, poorer performance in reading function words than content words (for each patient and each language chi-square significant in each case at  $p < .02$  or beyond), and an

Table 2. Scores on tests administered to P.D, J.W.T, and M.J

<i>Tests</i>		<i>P.D</i>	<i>J.W.T</i>	<i>M.J</i>
Pyramid & Palm Trees				
(a) Picture–picture version		49 (52)	49 (52)	50 (52)
(b) Word–word version		47 (52)	49 (52)	49 (52)
PALPA 47 (spoken word–picture matching)		37/40	38/40	—
PALPA 48 (written word–picture matching)		34/40	37/40	32/40
PALPA 31				
(word reading aloud: imageability & freq)	HI/HF	16/20	14/20	18/20
	HI/LF	10/20	13/20	17/20
	LI/HF	2/20	9/20	13/20
	LI/LF	0/20	6/20	11/20
WELSH (translated version)				
	HI/HF	15/20	17/20	—
	HI/LF	9/20	13/20	
	LI/HF	5/20	5/20	
	LI/LF	1/20	2/20	
PALPA 32(grammatical class reading)				
Nouns		8/20	12/20	13/20
Adjectives		7/20	12/20	15/20
Verbs		4/20	11/20	12/20
Function		0/20	4/20	4/20
WELSH (translated version)				
Nouns		9/20	10/20	—
Adjectives		5/20	8/20	
Verbs		2/20	4/20	
Function		1/20	3/20	
PALPA 35 (Regularity of reading English)				
Regular words		17/30	21/30	—
Irregular (exception) words		16/30	18/30	
PALPA 36 (Nonword reading in English)				
WELSH (nonword reading translated version)		0/24	3/24	9/24
		1/24	3/24	6/24
PALPA 8				
(Nonword repetition in English)		0/30	1/30	2/30
WELSH (translated version)		0/30	0/30	2/30
PALPA 9				
(imageability & frequency word repetition)	HI/HF	17/20	16/20	—
	HI/LF	14/20	15/20	
		10/20	5/20	
		9/20	3/20	
WELSH (translated version)				
	LI/HF			
	LI/LF			
	HI/HF	18/20	19/20	—
	HI/LF	14/20	15/20	
	LI/HF	12/20	14/20	
	LI/LF	5/20	5/20	
Letter–sound conversion (written letter–spoken sound)				
English		4/26	5/26	10/26
Welsh		7/28	8/28	8/18

*Note:* HI = high imageability. LI = low imageability. HF = high frequency. LF = low frequency. PALPA = Psycholinguistic Assessments of Language Processing in Aphasia. Maximum score in parentheses.

Table 3. *Picture naming in English and Welsh*

	P.D.		J.W.T.		M.J.	
	English	Welsh	English	Welsh	English	Welsh
Correct	99	71	124	104	124	132
Omission	40	39	39	36	22	19
Semantic error	46	46	26	36	39	38
Name of visually similar object	3	2	—	—	4	3
Circumlocution	26	12	19	4	19	5
Cross-linguistic semantic error <sup>a</sup>	3	16	6	6	6	9
Phonemic error	2	—	2	—	—	—
Morphological error <sup>b</sup>	—	—	1	—	—	—
Name correct language incorrect <sup>c</sup>	3	36	5	36	8	16
Total	222	222	222	222	222	222

<sup>a</sup>Semantic error given in nontarget language; <sup>b</sup>*orange* → *oranger*; <sup>c</sup>correct name given in nontarget language.

impairment in reading, writing, and repeating nonwords of both languages. Patient M.J. could not be tested so extensively but the pattern of her performance was similar (imageability effect in reading English words; poor nonword reading and nonword repetition in English and Welsh; poor function word reading in English). Letter-sound conversion was impaired in all three patients in both English and Welsh, and they all made semantic errors of reading (and naming) in each language (see Tables 3 and 4 below). These

findings establish that all three patients were deep dyslexic in both English and Welsh.

#### *Picture naming*

The data for picture naming in English and Welsh are shown in Table 3.

Examples of errors referred to as naming visually similar items are giving the response *wheel* to the stimulus item *button* or *screw* to *needle*.

McNemar tests showed that for patient P.D., picture naming was significantly better in

Table 4. *Reading in English and Welsh*

	P.D.		J.W.T.		M.J.	
	English	Welsh	English	Welsh	English	Welsh
Correct	147	83	152	121	151	159
Omission	30	65	17	37	21	31
Semantic error	15	30	12	21	14	16
Cross-linguistic semantic error <sup>a</sup>	1	6	2	7	6	2
Visual then semantic error <sup>b</sup>	1	—	—	—	—	—
Name of visually similar object	15	21	26	27	21	7
Circumlocution	10	7	10	9	8	5
Phonemic error	1	—	—	—	—	—
Morphological error	2	1	1	—	—	—
Name correct language incorrect <sup>c</sup>	—	9	2	—	1	2
Total	222	222	222	222	222	222

<sup>a</sup>Semantic error given in nontarget language; <sup>b</sup>*hanger* → *harbour* → *anchor*; <sup>c</sup>correct name given in nontarget language.

English than in Welsh ( $\chi^2 = 9.12, p < .01$ ). The same was true for J.W.T. ( $\chi^2 = 4.76, p < .05$ ). For patient M.J., naming was slightly but not significantly better in Welsh ( $\chi^2 = 1.33, p > .05$ ). (For all tests reported in this paper degrees of freedom = 1, and the direction is two-tailed.)

Chi-square comparison of semantic errors relative to all other errors of naming (excluding omissions) in English compared with Welsh showed no significant effect for any of the three patients ( $p > .05$ ). This was also the case when the analyses were repeated taking account of failures to respond (omissions) as well as errors.

### *Reading aloud*

The data for reading in English and Welsh are shown in Table 4.

McNemar tests showed that for patients P.D. ( $\chi^2 = 42.67, p < .001$ ) and J.W.T. ( $\chi^2 = 10.80, p < .01$ ) reading was significantly better in English than in Welsh. For patient M.J. reading was slightly but not significantly better in Welsh than in English ( $\chi^2 < 1$ ).

Chi-square tests comparing semantic errors relative to all other errors (excluding omissions) of reading in Welsh versus English gave the following results: For P.D.,  $\chi^2 < 1$ , for J.W.T.,  $\chi^2 = 1.02$ ; for M.J.,  $\chi^2 = 3.18 (p > .05$  in each case). Equivalent results were obtained when the analyses were repeated taking account of failures to respond (omissions) as well as errors. Thus semantic errors were not proportionally more frequent in one language than in the other.

### *Reading versus picture naming*

We compared reading with naming performance in each of the two languages of our patients. McNemar tests showed that for P.D., reading in English was significantly more accurate than picture naming ( $\chi^2 = 28.10; p < .001$ ) but not in Welsh ( $\chi^2 = 1.90, p > .05$ ). For J.W.T., too, reading in English was significantly better than naming ( $\chi^2 = 9.33, p < .01$ ); the difference between the two tasks narrowly failed to reach significance in Welsh ( $\chi^2 = 3.48, p > .05$ ). For patient M.J., reading was significantly better

than naming in both English ( $\chi^2 = 10.57, p < .01$ ) and Welsh ( $\chi^2 = 9.72, p < .01$ ).

For responses given in English, comparison of semantic and other errors in picture naming versus reading (see Tables 3 and 4) gave the following results. For P.D.,  $\chi^2 = 1.36 (p > .05)$ ; for J.W.T.,  $\chi^2 = 4.80 (p < .05)$ ; for M.J.,  $\chi^2 = 5.80 (p < .05)$ . Thus in English the latter two patients made proportionally more semantic errors, relative to other types of error, in naming than in reading.

For responses given in Welsh, the corresponding chi-square values for semantic errors in naming versus reading were not significant for any of the three patients ( $p > .05$  in each case).

The chi-square analyses comparing semantic errors in picture naming versus reading in each of the two languages were repeated taking account of failures to respond (omissions) as well as errors. In English, P.D. but not the other two patients showed significantly more semantic errors in picture naming than in reading ( $\chi^2 = 5.83, p < .05$ ). In Welsh, only M.J. showed a significantly greater proportion of semantic errors in picture naming ( $\chi^2 = 3.89, p < .05$ ).

## Discussion

It has been argued that the summation hypothesis can account for an apparent difference between transparent and opaque orthographies in the frequency of semantic errors of reading made by brain-damaged subjects. According to Miceli et al. (1994), a transparent orthography is relatively protected from the production of semantic paralexias. We therefore compared reading in English and Welsh by bilingual deep dyslexic participants. If Miceli et al. are correct, we should have observed relatively more semantic paralexias in English than in Welsh. Our data provide a clear refutation of this prediction; there were not more semantic errors made by our patients in reading English than in reading the corresponding Welsh words.

The production of semantic errors of reading and/or writing has been held to require the presence of impaired sublexical conversion



mechanisms, since otherwise intact conversion procedures would “block” the output of semantic errors (Patterson & Marcel, 1977; see papers in Caramazza & Hillis, 1990; Coltheart, Patterson, & Marshall, 1980; Friedman, 1996; Hillis & Caramazza, 1991; Miceli et al., 1999; Southwood & Chatterjee, 2000; Nickels, 1992). If this is true, then there would be no reason to expect any difference in semantic paralexias between deep and shallow orthographies when the orthographic-phonological sublexical conversion route is totally abolished since the means of “blocking” semantic errors would be unavailable for both languages. All else being equal, semantic errors in the two languages would be “free” to arise with approximately equal frequency in reading (as in picture naming).

Certainly all of our patients (in common with other deep dyslexics) had a severely impaired sublexical conversion route. However, some residual capacity for converting from letter to sound remained available; all three patients performed poorly but at above-chance level on letter-sound conversion in both languages. Thus there is little or no reason to argue that our patients did not provide a suitable test of the summation hypothesis as applied to reading in a shallow (transparent) and a deep (opaque) orthography. Our failure to confirm the prediction of the summation hypothesis concerning semantic errors therefore argues against any straightforward version of its application to languages differing in orthographic depth as outlined by Miceli et al. (1994). Indeed, the hypothesis predicts that there should be more semantic errors made in response to regular words than to irregular words. A glance at the published literature (e.g. Beaton, Guest, & Ved, 1997) suggests that this is not the case, and it certainly did not apply in the present study.

When all is said and done concerning the irregularity of the English language, it remains improbable that phonological recoding of irregular words (which would produce regularization errors in reading) would not provide some useful information. Between the correct pronunciation and a regularized pronunciation there will always be

considerable phonemic overlap even in the case of such highly irregular or exception words as *yacht* or *colonel*. This being so, it is likely that there will be only very few occasions on which a damaged conversion procedure will provide less useful information in a deep orthography than in a shallow one. Even if Miceli et al. (1994) are correct that, following brain damage, more sublexical information will be preserved in a transparent (shallow) than an opaque (deep) orthography, almost always sufficient information from each orthography would survive to block the output of many semantic errors. If this is so, then arguably there is no basis for the prediction that there will be fewer semantic errors made in reading a shallow than a deep orthography.

The interpretation of results obtained from bilingual patients is not without a number of potential problems. These include the level of competence achieved in each language, the relative age and order of acquisition of the two languages, and so on (for discussion see Paradis, 2004). Of our three patients, two considered themselves to be dominant in English (and named and read more items correctly in English than Welsh) while the third patient considered Welsh to be her dominant language (and named and read more items correctly in Welsh than English). In all three cases, however, there is no evidence of proportionally more semantic errors of reading in one language than in the other. Neither language dominance nor orthographic depth therefore appears to have influenced the relative frequency of production of semantic errors in our patients.

For all three of our patients, reading accuracy was better than picture-naming performance in both languages (significantly so for English but in Welsh significant only for M.J. though close to significance for J.W.T.). This is consistent with the availability of some sublexical support in reading. Furthermore, it is possible that some degree of *implicit* phonological processing was also available to each of our patients (Buchanan, Hildebrandt, & MacKinnon, 1994, 1996; Buchanan, McEwen, Westbury, & Libben, 2003; Katz & Lanzoni, 1992). An alternative

explanation of the better reading than naming accuracy in our patients draws on the notion that the semantic system is not unimodal (or supramodal) but is organized by “modality” of input (Beavois, 1982; Shallice, 1988; for contrary view see Caramazza, Hillis, Rapp, & Romani, 1990; Hillis & Caramazza, 1995; for review and alternative formulation see Plaut, 2002). On this account, information presented via the spoken or written word enters a verbal semantic system whereas (nonverbal) information received through vision enters a visual semantic system. The verbal semantic system has direct access to the speech output mechanisms while the visual nonverbal system has only indirect access via communication with the verbal system. These two systems are assumed to be in contact but in certain cases of brain damage there may be some impediment to transfer of information between the two systems. Direct access to speech output mechanisms from the verbal semantic system would explain better reading than naming performance for corresponding items.

Turning now to another feature of our results, all three patients made proportionally more semantic errors, relative to other types of error, in naming than in reading when responding in English (though the statistical significance of the effect varied according to whether failures to respond—omissions—were included in the analysis). When tested in Welsh, however, only one of the patients showed significantly more semantic errors in naming than in reading, and that only when omissions were included. It is possible that residual phonological support was greater for English than for Welsh reading, although the data shown in Table 2 (and inspection of error responses to nonword stimuli) do not, in fact, support this idea. Nonword reading and letter-sound conversion were approximately equivalent for the two languages.

Finally, in contrast to the dual-route account of reading, the so-called triangle model (Patterson & Lambon-Ralph, 1999; Seidenberg & McClelland, 1989) does not include separate lexical and sublexical routes. Instead a single route is used for reading both familiar words and unfamiliar letter

strings. In this model, there are connections between orthography and phonology and between each of these and the semantic system. Differences in orthographic depth are captured by differences in degree of consistency in the mapping between spelling (orthography) and pronunciation (phonology), which are picked up by the learning algorithm and encoded by the strength of the connections (Seidenberg, 1992). The computation of phonology is constrained by semantic processing: The weaker the connections between orthography and phonology, the greater the influence of semantics. Damage to phonological-processing mechanisms would produce increased reliance on semantic processing. An impairment of semantic processing, a feature of dual-route accounts of at least some (central) types of deep dyslexia (Dickerson & Johnson, 2004), in addition to impaired phonological-processing mechanisms, implies that semantic errors will be produced in response to some target words, even in the context of some degree of preserved phonological processing. The triangle model might therefore predict that inherently weaker connections between orthography and phonology for an orthographically deep than for a shallow language, combined with a given degree of semantic impairment, would lead to a greater likelihood of semantic errors being made by a deep dyslexic patient reading an opaque (deep) than a transparent (shallow) language. That is, both the triangle model and the “summation version” of the dual-route model at first blush might be thought to make the same prediction—more semantic errors in reading a deep than a transparent language. However, for the reasons outlined above, such a prediction may not, in fact, be appropriate. Certainly, our findings do not support such a prediction though, of course, they do not constitute evidence against the summation (or triangle) hypothesis as such.

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