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New evidence for morphological errors in deep dyslexia ☆

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Abstract

Morphological errors in reading aloud (e.g., *sexist* → *sexy*) are a central feature of the symptom-complex known as deep dyslexia, and have historically been viewed as evidence that representations at some level of the reading system are morphologically structured. However, it has been proposed (Funnell, 1987) that morphological errors in deep dyslexia are not morphological in nature but are actually a type of visual error that arises when a target word that cannot be read aloud (by virtue of its low imageability and/or frequency) is modified to form a visually similar word that can be read aloud (by virtue of its higher imageability and/or frequency). In the work reported here, the deep dyslexic patient DE read aloud lists of genuinely suffixed words (e.g., *killer*), pseudosuffixed words (e.g., *corner*), and words with non-morphological embeddings (e.g., *cornea*). Results revealed that the morphological status of a word had a significant influence on the production of stem errors (i.e., errors that include the stem or pseudostem of the target): genuinely suffixed words yielded more stem errors than pseudosuffixed words or words with non-morphological embeddings. This effect of morphological status could not be attributed to the relative levels of target and stem imageability and/or frequency. We argue that this pattern of data indicates that apparent morphological errors in deep dyslexic reading are genuinely morphological, and discuss the implications of these errors for theories of deep dyslexia.

Keywords: Morphology; Morphological errors; Deep dyslexia; Reading aloud; Visual word recognition; Acquired dyslexia; Visual errors

1. Introduction

Behavioural evidence from adults without language impairment suggests strongly that words comprising more than one morpheme (e.g., prefixed words, suffixed words, and compound words) are analyzed in a decomposed manner (i.e., in terms of their morphemic constituents) in the language system. This evidence has been gathered from across many of the world's languages (e.g., Arabic, Dutch, English, French, Finnish, German, Hebrew, Italian, Spanish, Serbian; see e.g., Frost & Grainger, 2000; Frost, Grainger, & Rastle, 2005), and pertains to the perception of both printed and spoken words (e.g., Frost, Forster, & Deutsch, 1997; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Rastle, Davis, Marslen-Wilson, & Tyler, 2000; Rastle, Davis, & New, 2004; Taft & Forster, 1975) as well as to the production of spoken words (e.g., Levelt, Roelofs, & Meyer, 1999; Melinger, 2003; Roelofs & Baayen, 2002). We are concerned in this article with morphologically structured representations in the reading system, and specifically with the manner in which such representations may be revealed in individuals with acquired disorders of reading.

Our investigation focuses in particular on the symptom-complex known as deep dyslexia (Marshall & Newcombe, 1966, 1973, see also Coltheart, Patterson, & Marshall, 1980/1987), within which morphological errors in reading aloud are a primary feature. Deep dyslexia is an acquired disorder

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of reading characterized by a number of co-occurring impairments, including (a) semantic errors in reading aloud (e.g., *kitchen* → *cooking*); (b) visual errors in reading aloud (e.g., *brothel* → *brother*); (c) poor reading aloud of abstract words relative to concrete words; (d) poor reading aloud of function words (e.g., *so*, *as*, *the*); (e) the complete inability to read aloud non-words; and (f) poor reading aloud of morphologically complex words. Morphological impairment in these individuals has been evidenced both by poorer reading aloud of morphologically complex words than phonologically matched simple words (e.g., *handy* versus *dandy*; e.g., Job & Sartori, 1984) and by the existence of morphological errors in reading aloud formed by the deletion, addition, or substitution of an affix (e.g., *swimmer* → *swim*; *initiate* → *initiative*; *thickly* → *thicken*; e.g., Patterson, 1980). The existence of morphological errors in deep dyslexia has historically been viewed as evidence that representations at some level of the reading system are morphologically structured—and has therefore required theoretical accounts of deep dyslexia to postulate specific mechanisms, which when damaged give rise to morphological errors (see e.g., Morton & Patterson, 1980).

Research in more recent years has, however, challenged the inference that morphological errors in deep dyslexia necessarily reflect a level of the reading system at which words are represented in terms of their morphemic constituents. Specifically, researchers have questioned whether morphological errors might be a consequence of damage to the very same procedures that give rise to the visual and semantic errors with which they co-occur (i.e., that 'morphological' errors are actually visual or semantic errors; see e.g., Badecker & Caramazza, 1987; Castles, Coltheart, Savage, Bates, & Reid, 1996; Funnell, 1987; Plaut & Shallice, 1993, for discussion). One particularly influential claim (Funnell, 1987, see also Funnell, 2000) is that ostensibly morphological errors are actually visual errors, which arise when a target word is too low in imageability and/or frequency to be read aloud. In these circumstances, a visually similar word that can be read aloud (by virtue of its higher imageability and/or frequency) is formed by the addition, subtraction, or substitution of letters (see also Shallice & Warrington, 1975). The result can be an error that appears morphological in nature (e.g., *soloist* → *solo*). Identifying the true nature of these errors is, of course, crucially important for developing a coherent theoretical account of deep dyslexia. The aim of this article is to evaluate Funnell's (1987) claim concerning the mechanism that gives rise to errors that appear morphological in nature.

2. Funnell (1987): A closer look

Funnell (1987) reasoned that if "stem errors" (i.e., errors that preserve the stem of morphologically complex words; e.g., *<u>solo</u>ist* → *<u>solo</u>*, *<u>swim</u>mer* → *<u>swim</u>ming*) reflect a morphologically structured level of representation, then they should occur only for target words that are genuinely affixed (i.e., those words that could be lexically represented in a decomposed manner; e.g., *soloist* as [*solo*] + [*ist*]). Conversely, if stem errors are a type of visual error that arises when a target word is too low in imageability and/or frequency to be read aloud, then they may occur whenever a target word contains an embedding that is higher in imageability and/or frequency than the target, irrespective of the morphological status of the target word (e.g., they may occur in *<u>corn</u>er* or *<u>bill</u>ow*, which are not morphologically complex). Funnell (1987) pointed out that this possibility could not have been examined in previous investigations since phonological controls for morphologically complex words used in those investigations did not contain embedded words (e.g., *handy* versus *dandy*; Kay, Lesser, & Coltheart, 1996). Funnell (1987) tested her predictions in two patients previously shown to exhibit morphological errors in reading aloud (JG and CJ), only one of which fitted the profile of a deep dyslexic (JG). We focus on JG's performance in particular.

In her first experiment, Funnell (1987) examined JG's reading aloud performance on sets of genuinely suffixed (e.g., *shadowy*) and pseudosuffixed (e.g., *irony*) words matched closely on word imageability, word frequency, stem imageability, and stem frequency. JG produced stem errors for each type of item (e.g., *shadowy* → *shadow*; *irony* → *iron*). Further, although he produced over twice as many stem errors for genuinely suffixed words as for pseudosuffixed words (30 versus 13), this difference was non-significant. Posthoc analyses revealed that the occurrence of stem errors in JG's reading aloud was particularly related to the relative levels of target and stem imageability: stem errors occurred primarily when stems were more imageable than targets. This posthoc analysis motivated Funnell's (1987) third experiment. She selected a single set of 85 words, 33 of which were genuinely suffixed words (e.g., *shadowy*), 33 of which were pseudosuffixed words (e.g., *corner*), and 19 of which had other embeddings (e.g., *cowl*). She classified these 85 words into three groups based only on the relative levels of target and stem imageability (i.e., she did not consider word type as an additional variable). Funnell (1987) found that when stems were more imageable than targets, JG tended to produce stem errors; when targets were more imageable than stems, JG tended to produce correct responses; and when targets and stems were both low in imageabilty, JG tended to produce omissions and other visual errors. On the basis of these data, Funnell (1987, p. 525) argued, "There is no evidence to suggest that these errors reflect damage to a stage of processing in which root morphemes and suffixes are represented as independent orthographic entities."

Funnell (1987, Experiment 3) did not report whether word type (i.e., genuinely suffixed, pseudosuffixed, or embedded) had an influence on stem errors over and above the influence of relative levels of target and stem imageability. However, her raw data indicate that this is a possibility: JG produced stem errors for 18 of the 33 genuinely suffixed words (54.5%), 9 of the 33 pseudosuffixed words (27.3%), and 3 of the 19 words with other embeddings (15.8%). These data should be treated with some caution, of course, since the three conditions were not group-wise matched on the variables that Funnell (1987) showed to be influential in the production of JG's stem errors (i.e., relative levels of target and stem imageability). However, paired with the fact that JG produced over twice as many stem errors for genuinely suffixed targets as for pseudosuffixed targets (30 versus 13) in Funnell's first experiment, these data may indicate that the morphological status of the target word has an independent influence on the production of stem errors in deep dyslexia.

We now turn to an examination of these issues in another individual with deep dyslexia, DE. Our aim is to investigate whether the production of stem errors in deep dyslexia is influenced by the morphological status of the target word—over and above any influence of the relative levels of target and stem imageability and/or frequency. We use a larger and better-controlled set of stimuli than was used by Funnell (1987), and take advantage of specialized statistical techniques designed to reveal independent effects of morphological status and other variables (e.g., target and stem imageability) on the production of stem errors.

3. Case history

At the age of 16, he was involved in a motor-scooter accident that was likely followed within 24 h by a middle cerebral artery stroke. These injuries left him with extensive language disabilities and moderate right hemiplegia (see Tyler, Randall, & Marslen-Wilson, 2002, for further information). A CT scan in 1978, confirmed by an MRI scan in 1996, showed extensive damage to the left hemisphere, involving large sections of the middle and posterior parts of the frontal lobe and most of the temporal lobe (see Fig. 1). DE has worked as a store-keeper since his accident, and was 45 years of age at the time of testing.

DE provides one of the earliest-reported cases of deep dyslexia (Patterson & Marcel, 1977), and he has been studied extensively ever since (see e.g., Coltheart, 1980a/1987a; Tables 2.1–2.6; Marslen-Wilson & Tyler, 1997; Morton & Patterson, 1980; Patterson & Marcel, 1977; Patterson, 1978, 1979, 1980; Tyler, 1992; Tyler, Moss, & Jennings, 1995; Tyler & de Mornay-Davies et al., 2002). These investigations have established beyond doubt that DE fits the deep dyslexia profile: he produces the hallmark semantic, visual, and morphological errors in reading aloud; he shows a concreteness effect in reading aloud; he is extremely poor at reading aloud function words; and he cannot read aloud non-words at all.

4. Stimuli and procedure

One hundred and seventy five words were selected from the CELEX English database (Baayen, Piepenbrock, & van Rijn, 1993) for inclusion in three conditions. The 'genuinely suffixed' condition comprised 52 morphologically complex suffixed words (e.g., *grower*, *meanness*), which were generally semantically transparent (i.e., their meanings could be derived from the meanings of their constituents). These

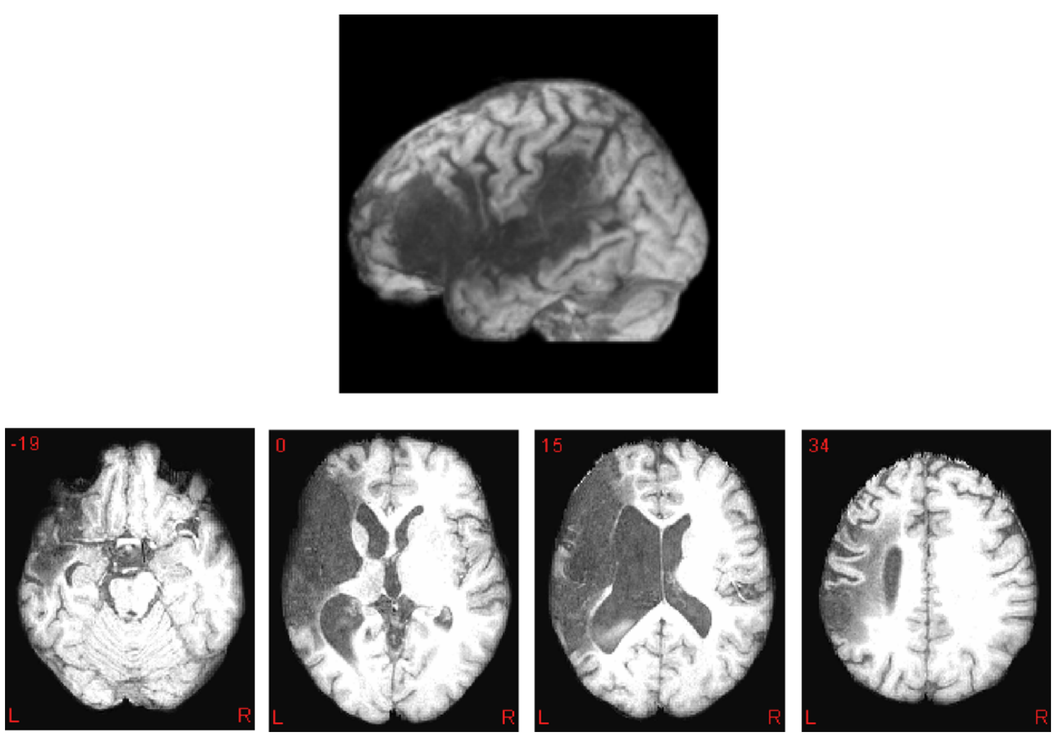

Fig. 1. (Top) Surface reconstruction of DE's left hemisphere. (Bottom) Axial slices from a spatially normalized T1 weighted MR image showing the extent of DE's damage, which involves most of the left perisylvian language areas including the LSTG and LMTG and extending into the left inferior frontal cortex. Talairach z-dimensions are given in the top left corner of each panel. Left = Left.

were all derivationally complex forms, and none of them had inflectional endings. The 'pseudosuffixed' condition comprised 62 morphologically simple words such as *beaker* and *bully*. These words had the surface form of morphological complexity since they could be parsed into stems and suffixes (e.g., [*beak*] + [*er*], [*bull*] + [*y*]), but they had no actual etymological or semantic relation to their embedded stems. The 'embedded' condition comprised 61 morphologically simple words, all of which contained a potential embedded stem (e.g., *cornea*). Since none of these potential stems were followed by an English suffix, there was no basis for a decomposition of the embedded words into morphemic constituents.

Words in the three conditions were group-wise matched as closely as possible on word frequency, stem frequency, word imageability, and stem imageability. Frequency values were extracted from the CELEX database of English written wordforms (Baayen et al., 1993). Imageability ratings on a 7-point scale (with 7 representing "highly imageable" and 1 representing "not imageable") were collected from two groups of 19 participants from the University of Cambridge. One group of participants rated the imageability of half of the words in each condition and the stems of the remaining words in that condition; the other group of subjects rated the opposite half of words and stems in each condition.

Frequency and imageability values of target words and embedded stems are displayed in Table 1. There were no significant differences across condition in the levels of word frequency, [$F(2,172) = 2.52$, $p = .083$], stem frequency, [$F(2,172) = .231$, $p = .794$], whole-word imageability, [$F(2,172) = 2.62$, $p = .076$], or stem imageability, [$F(2,172) = 1.67$, $p = .191$]. Although none of these variables differed significantly by condition, trends toward significance did exist. Thus, in addition to the matching carried out here, we dealt with small differences between word types statistically in the analyses of the data. Stimuli are listed in the Appendix A together with DE's reading aloud responses to them.

One hundred and twenty five morphologically simple filler words, which did not contain embedded words, were generated. These words were generally highly imageable (with average ratings of over 500 in the MRC Psycholinguistic Database; Coltheart, 1981), and were included both to disguise the presence of word embeddings in the stimulus list and to ensure that DE would be able to read a significant number of words in the relatively lengthy testing session.

DE was presented with target and filler words in random order for reading aloud. Words were typed onto note cards, and the experimenter recorded responses during the session. DE was tested on these words twice at an interval of approximately six months.

5. Results

DE's reading aloud responses for both testing sessions are provided in the Appendix A. He made numerous errors in reading aloud the target words. As expected given his deep dyslexia profile, his errors included semantic errors (e.g., *caret* → *jewel*, *lotion* → *cream*), visual errors (e.g., *haggle* → *haggis*, *muster* → *muscles*), visual then semantic errors (e.g., *pastor* → *pasta*, *spaghetti*), morphological errors (e.g., *sexist* → *sexy*), and morphological then semantic errors (e.g., *exactly* → *ex-sing something*). Errors also included a number of novel morphological constructions (e.g., *arsonist* → *arsoner*; *goddess* → *godery*; *illness* → *illy*).

Responses from both testing sessions were added together in order to increase the power of the analyses and to ensure that the effects we observed were not particular to a specific testing session. For this reason, session was included as a covariate in all analyses. Responses were scored as correct if DE initially produced the correct answer, or if he made an immediate self-correction following an incorrect response. There were five occasions in which DE produced a successful self correction: two occasions for the suffixed items (*killer* → *kill*, *killer*; *buzzer* → *bell*, *no buzzer*); one occasion for the pseudosuffixed items (*billion* → *million*, *billion*); and two occasions for the embedded word items (*dingo* → *australian*, *dingo*; *billow* → *bill*, *billow*).

Incorrect responses were then examined for the presence of stem errors. A stem error was defined as any incorrect response which contained the stem. Thus, a stem error could be the result of deletion of an ending (e.g., *irony* → *iron*) or the substitution of an ending—whether that substitution be an affix (e.g., *swimmer* → *swimming*) or another type of ending (e.g., *pastel* → *pasta*). Instances in which DE produced the entire target word with an inflectional ending (which was always –s, e.g., *bunion* → *bunions*; *sweetie* → *sweeties*) were not considered to be stem errors. Table 2 displays percentages of correct responses, stem errors, and other kinds of error across the three conditions.

We analyzed correct responses and stem errors using logistic regression analyses. These analyses enabled us to

Table 1
Stimulus characteristics (means and standard deviations) for words in each condition

	Word frequency	Word imageability	Stem frequency	Stem imageability
Suffixed	Mean: 13.35	Mean: 4.00	Mean: 91.94	Mean: 4.49
	SD: 25.24	*SD*: 1.39	*SD*: 160.16	*SD*: 1.54
Pseudosuffixed	Mean: 30.90	Mean: 4.18	Mean: 123.32	Mean: 4.79
	SD: 71.08	*SD*: 1.47	*SD*: 302.21	*SD*: 1.69
Embedded	Mean: 14.50	Mean: 4.59	Mean: 120.93	Mean: 5.05
	SD:29.48	*SD*: 1.41	*SD*: 305.87	*SD*: 1.59

Table 2
Percentages of correct responses, stem errors, and other errors for words in each condition

	Correct responses (%)	Stem errors (%)	Other errors (%)
Suffixed	35.58	51.43	12.99
Pseudosuffixed	43.55	26.61	29.84
Embedded	51.64	30.32	18.04

Table 3
Percentages of deletion errors and substitution errors for each condition as a subset of the incorrect responses

	Deletion (e.g., swimmer → swim) (%)	Substitution (e.g., tally >taller) (%)
Suffixed	19.40	62.68
Pseudosuffixed	18.57	20.00
Embedded	30.51	18.64

assess the influence of condition on these binary dependent measures while accounting for any influences of the continuous covariates target imageability, stem imageability, target frequency, and stem frequency. Session was also included as a binary covariate in these analyses. For each analysis, we tested the statistical significance of these independent variables with the Wald test (hereafter, *W*).

Results revealed no influence of condition on the production of correct responses [$W(2) = 1.38$, n.s.]. Of the covariates, word imageability had the strongest influence on the production of correct responses [$W(1) = 37.29$, $p < .001$]: words of high imageability elicited more correct responses than words of low imageability. There were no effects of stem imageability [$W(1) = 1.51$, n.s.], word frequency [$W(1) = .79$, n.s.], stem frequency [$W(1) = 1.13$, n.s.], or session [$W(1) = .88$, n.s.] on the production of correct responses.

Although there was no influence of condition on the production of correct responses, there was a numerical difference across these conditions. Therefore, stem errors were analyzed as a subset of the incorrect responses. Crucially, these analyses did reveal a significant effect of condition on the production of stem errors [$W(2) = 16.26$, $p < .001$]: genuinely suffixed words elicited more stem errors than both pseudosuffixed words [$W(1) = 16.26$, $p < .001$] and embedded words [$W(1) = 6.06$, $p = .014$]. The production of stem errors was also influenced by stem imageability [$W(1) = 6.34$, $p = .012$] and marginally by stem frequency [$W(1) = 3.52$, $p = .061$] indicating that when targets were too low in imageability to be named correctly, they were likely to yield stem errors if their stems were high in imageability and/or frequency. There were no effects of session [$W(1) = .23$, n.s.], word frequency [$W(1) = 1.32$, n.s.], or word imageability [$W(1) = 2.15$, n.s.] on the production of stem errors.

The preceding analysis establishes that DE's production of stem errors was influenced by the morphological status of words that he read aloud: DE made more stem errors when words were genuinely suffixed than when they were pseudosuffixed or contained embedded words. We therefore sought to learn more about the nature of the effect of condition on stem error production. Table 3 shows the percentage of cases across the three conditions in which DE produced 'deletion' and 'substitution' errors. 'Deletion' errors occurred when the stem was produced alone (e.g., *swimmer* → *swim*); 'substitution' errors occurred when the stem was produced with an incorrect affix (e.g., *madly* → *madness*). Occasionally, DE produced both a deletion error and a substitution error for a single item (e.g., *tallish* → *tall*, *taller*); in these rare instances, the stem error was counted as both a deletion and a substitution. It is important to note that the figures in Table 3 are expressed as a percentage of the incorrect responses made in each condition. These figures do not sum to 100% because they do not include DE's other errors (e.g., semantic errors).

Logistic regression analyses on the incorrect responses, which controlled for the four predictor variables plus session, revealed clearly the source of the effect of condition on stem error production. While deletion errors were not influenced by condition [$W(2) = 2.04$, n.s.], the analysis of substitution errors revealed a highly significant effect of condition [$W(2) = 28.42$, $p < .001$]: genuinely suffixed words yielded more substitution errors than either pseudosuffixed words [$W(1) = 20.75$, $p < .001$] or embedded words [$W(1) = 18.84$, $p < .001$].[1]

6. General discussion

Morphological errors in reading aloud (e.g., *soloist* → *solo*, *swimmer* → *swimming*) have long been considered a central feature of the symptom-complex known as deep dyslexia (see e.g., Coltheart et al., 1980/1987). Some investigators, however (e.g., Funnell, 1987, 2000; Plaut & Shallice, 1993), have questioned whether these errors genuinely reveal morphologically structured representations in the reading system, and have argued instead that they may arise from the same sources as the visual and semantic errors with which they co-occur. In particular, it has been claimed that morphological errors are a type of visual error that arises when a target word is too low in imageability and/or frequency to be read aloud correctly. In these circumstances, the target word may be altered by adding, subtracting, or substituting letters such that a word higher in imageability and/or frequency is formed. While the result may appear to be a morphological error (e.g., *soloist* → *solo*), it is argued that careful scrutiny of "stem errors" in matched morphologically simple target words (e.g.,

[1] It is interesting to note that while this effect of morphological status was observed only on DE's substitution errors (of which there were a substantial number), JG (Funnell, 1987) made mostly errors of deletion and showed no effect of morphological status. It is difficult to compare these two patients directly because they were tested on different stimuli. However, we find it unlikely that an appropriate investigation of JG's few substitution errors would have yielded an effect of morphological status. Further research is needed to determine whether morphological errors are restricted to a subset of deep dyslexic patients.

irony → *iron*) suggests otherwise (Funnell, 1987). Our data are inconsistent with this claim. DE's reading aloud performance demonstrates that the morphological status of a word *does* influence the production of stem errors. Genuinely suffixed words yield more stem errors than either pseudosuffixed words or words containing other embeddings—an effect of morphological status that cannot be attributed to the relative levels of target and stem imageability and/or frequency.

Although our data indicate that morphological errors in deep dyslexic reading cannot be regarded as visual errors, some may argue that there are other means of accounting for these data without reference to morphologically structured representations in the reading system. One possibility is that morphological errors in deep dyslexia reflect a type of mixed visual and semantic error (e.g., Plaut & Shallice, 1993), in which a word close in orthography and meaning to the target is produced when the target cannot be read aloud. These errors would occur more often for morphologically complex words than for morphologically simple words because—by definition—for all morphologically complex words there is at least one other word similar in orthography and meaning (e.g., *cleaner* → *clean*; *darkness* → *dark*). While we cannot evaluate this possibility fully, we do not believe that our data are entirely consistent with it. To be specific, 28% of DE's substitution errors were novel morphological constructions (e.g., *arsonist* → *arsoner*, *illness* → *illy*, *brainless* → *brainly*, *goddess* → *goddery*) in which the appropriate affix was replaced by an inappropriate one. If DE were simply selecting an orthographically and semantically similar word in cases in which targets could not be read aloud, then it is unclear how a nonword response would be produced.

Rather, these types of errors implicate a level of representation at which semantically transparent complex words are analyzed in terms of their morphemic constituents. This claim is nicely consistent with a growing body of evidence for a level of 'morpho-semantic' decomposition in unimpaired readers, which is revealed when tasks that tap central-semantic levels of the reading system (e.g., visual priming with fully visible primes) are used. Under these conditions, for example, Rastle et al. (2000) reported robust priming of stem targets (e.g., *dark*) by morphologically related words (e.g., *darkness*) relative to unrelated controls. Conversely, priming of stem targets (e.g., *corn, broth*) by pseudosuffixed words (e.g., *corner*) or words with other non-morphological embeddings (e.g., *brothel*) was non-significant. 'Morpho-semantic' decomposition has been modeled in both classical localist and distributed-connectionist terms as a level of representation that resides between orthographic and semantic representations—a level of representation at which the local or distributed representations of semantically transparent complex words overlap the local or distributed representations of their stems (e.g., Giraudo & Grainger, 2000; Plaut & Gonnerman, 2000; Raveh & Rueckl, 2000).

Although DE's performance appears to suggest a level of 'morpho-semantic' representation for which there is also evidence from unimpaired readers, we see some difficulties in explaining his behaviour in terms of damage to the normal reading system. Some investigators (e.g., Morton and Patterson, 1980/1987; Plaut & Shallice, 1993) have argued that deep dyslexia may be explained by multiple lesions to the left-hemisphere reading system, which leave the patient reading solely through a damaged semantic system with no other lexical or non-lexical means of converting orthography to phonology. There are reservations about this view of deep dyslexia, however, the most serious of which is the observation that the multiple behavioural features of deep dyslexia (presumed to arise from multiple functional lesions; e.g., Morton and Patterson, 1980/1987) do not appear to dissociate. These reservations have prompted other investigators (e.g., Coltheart, 1980b/1987b; Coltheart, 2000; Saffran, Bogyo, Schwartz, & Marin, 1980/1987; Weekes, Coltheart, & Gordon, 1997) to argue that deep dyslexia reflects access to a right-hemisphere reading system not normally used by unimpaired readers. On this theory, the deep dyslexic reader activates orthographic lexical entries in the right hemisphere, which in turn activate right-hemisphere semantic representations presumed to be relatively impoverished for abstract words (Coltheart et al., 1980/1987; Saffran et al., 1980/1987). Right-hemisphere theories are not committed to a view on the locus of phonological representations for speech output. The right-hemisphere hypothesis is argued to explain the core features of deep dyslexia (see Coltheart et al., 1980/1987; Saffran et al., 1980/1987), and has garnered support from a variety of sources including lateralized presentation to split-brain patients (see Coltheart et al., 1980/1987; Michel, Henaff, & Intrilligator, 1996; Saffran etal.,1980/1987), neuroimaging of deep dyslexic readers (Coltheart, 2000; Weekes et al., 1997), and the study of left-hemispherectomy patients (e.g., Patterson, Vargha-Khadem, & Polkey, 1987).

How might DE's performance in reading morphologically complex words aloud be explained on the right-hemisphere theory of deep dyslexia? Our data suggest, first of all, that DE's deletion errors do not depend on the morphological status of target words. Many of these errors could therefore be visual errors (Funnell, 1987), and ascribed to the same mechanism that underlies visual errors in the right hemisphere (Coltheart et al., 1980/1987; see also Shallice & Warrington, 1975). Our data also suggest, however, that DE makes substitution errors that *do* depend on the morphological status of targets. If deep dyslexia does reflect right-hemisphere reading, then these data suggest that the right hemisphere is characterized by a form of lexical representation that captures the morphological properties of semantically transparent complex words. One specific possibility is that the right hemisphere is characterized by a level of morpho-semantic representation that resides between right-hemisphere orthographic and semantic lexical representations, at which semantically transparent complex words are analyzed in terms of their morphemic constituents. Substitution errors might then arise because the affix component (e.g., -ist) of a decomposed stimulus may not activate right-hemisphere semantic representations (presumed to be impoverished for abstract words; Coltheart et al., 1980/1987) sufficiently to drive speech production. In such cases, an alternative affix may be activated at the morpho-semantic level and produced together with the stem (cf., Shallice & Warrington's, 1975 account of visual errors). Further research is clearly needed, however, to establish fully this account of morphological errors in deep dyslexia. In particular, it would be desirable to seek further independent evidence that right-hemisphere lexical representations—like left-hemisphere lexical representations—are structured morphologically.

In summary, we have offered data that argue against the claims made by Funnell (1987) concerning the nature of morphological errors in deep dyslexia. These errors are not always a type of visual error that occurs when a target word that cannot be read aloud is modified (by the addition, subtraction, or substitution of letters) to yield a word higher in imageability and/or frequency that can be read aloud. Rather, these errors can be influenced significantly by the morphological status of target words. Irrespective of the particular account of deep dyslexia offered (e.g., Coltheart et al., 1980/1987; Morton and Patterson, 1980/1987), these data implicate a level of lexical representation that is organized on the basis of morphological relationships. Further research is needed to determine whether morphological errors are a general feature of deep dyslexia, or whether they are observed in only a subset of patients (see Funnell, 1987).

Appendix A

Stimuli and DE's reading aloud responses

Target	Condition	Response session 1	Response session 2	Word frequency	Word imageability	Stem frequency	Stem imageability
option	Suffixed	optimum, no idea	opting	16	1.74	0	1.55
partly	Suffixed	parted	c	72	1.79	487	3.25
blandly	Suffixed	L and B, land, dk	blankly	3	2	6	2
worthless	Suffixed	worthily	worthery, lot of money	5	2.11	99	2.5
goodness	Suffixed	good goodly	goodly	15	2.47	911	2.73
crabby	Suffixed	crabbing	c	1	2.5	5	6.75
wordy	Suffixed	words	words	0	2.58	212	5
teaser	Suffixed	tears	tea, dk	0	2.63	5	6.36
brainless	Suffixed	brain, dk, something	brainly	1	2.74	70	6.17
sickish	Suffixed	sickering	sickly	0	2.74	71	4.08
thickly	Suffixed	thicken, thickening	thickens	5	2.79	69	3.92
grower	Suffixed	grown	grown	0	2.82	96	3.73
sexist	Suffixed	sexy	sexy	3	2.84	129	5.33
meanness	Suffixed	meaning, mean	dk	2	2.95	296	2.58
madly	Suffixed	madness	madness	5	2.95	49	3.75
smoothly	Suffixed	smootly, same again	smoother	12	3	38	4.5
swiftly	Suffixed	swifty	c	16	3	12	3.73
willowy	Suffixed	willows	trees, can't say it	1	3.16	4	6.67
lovely	Suffixed	c	c	54	3.32	367	3.25
buffer	Suffixed	bluff	c	2	3.37	1	3.09
childish	Suffixed	child, dk	childly, dk	14	3.47	440	6.58
stockist	Suffixed	stocking	dk	0	3.53	64	4
arsonist	Suffixed	arsoner, dk	arson, dk	0	3.56	2	4.17
chilly	Suffixed	c	chills	6	3.58	10	3.5
killer	Suffixed	kill, killer	kill	12	3.84	86	4
tallish	Suffixed	tall, taller, wrong	c	0	3.89	68	5.58
bulky	Suffixed	c	c	6	4.21	22	3.25
talker	Suffixed	talking	talking	2	4.32	248	4.17
illness	Suffixed	illy	illery	36	4.37	57	3.08
crusty	Suffixed	c	c	1	4.53	7	5.58
birdie	Suffixed	c	c	1	4.61	44	6.92
washer	Suffixed	washing	washing	2	4.63	43	4.67
sweetie	Suffixed	sweeties	sweeties	1	4.68	48	5.25
scabby	Suffixed	scabs	scrabble, wrong	0	4.84	1	5.82
goddess	Suffixed	godistest	godery, dk	8	5	22	3.33
snowy	Suffixed	c	c	2	5.11	59	6.33
junkie	Suffixed	c	c	1	5.11	8	4.83
buzzer	Suffixed	bell, buzz	buzzing	2	5.16	3	3.91
woolly	Suffixed	c	c	3	5.47	23	6.55
curly	Suffixed	c	c	4	5.68	6	5.25

(continued on next page)

Appendix A (*continued*)

Target	Condition	Response session 1	Response session 2	Word frequency	Word imageability	Stem frequency	Stem imageability
tourist	Suffixed	tourists	c	19	5.74	40	3.36
hilly	Suffixed	c	c	2	5.84	72	6.64
artist	Suffixed	c	c	40	5.95	166	5.17
auntie	Suffixed	c	c	4	6.05	31	5.75
cabbie	Suffixed	australian, cab, american	c	0	6.06	10	6.58
actor	Suffixed	c	c	46	6.11	189	3.17
tanker	Suffixed	c	c	1	6.21	22	6.5
zipper	Suffixed	zip	zip	1	6.26	2	6.75
swimmer	Suffixed	swimming	swimming	2	6.89	25	5.27
election	Suffixed	vote	elect, dk	71	3.3	5	2.2
exactly	Suffixed	dk	ex, sing something	135	1.9	31	1.2
computer	Suffixed	computed	c	59	4.8	0	3
cower	Pseudosuffixed	no idea, cow	dk	0	3.11	23	6.92
adder	Pseudosuffixed	c	c	0	5.32	84	3
tuber	Pseudosuffixed	tubbing	tube	0	4.18	15	6.33
solder	Pseudosuffixed	soldier	soldier	0	4.06	60	2.67
burnish	Pseudosuffixed	burnly	burnly	0	2.94	27	4.83
rasher	Pseudosuffixed	bacon	bacon	0	4.95	11	5.58
bunion	Pseudosuffixed	bunions	c	0	4.72	4	6.58
tarnish	Pseudosuffixed	varnish	c	0	4.32	1	4.78
teeter	Pseudosuffixed	dk, teeth, wrong	c	0	3	0	5.67
muster	Pseudosuffixed	muscles, no idea	muster, wrong, like musty	1	1.72	925	2
pasty	Pseudosuffixed	pastry	cake, beforehand, pastry, dk	1	4.58	276	2.75
testy	Pseudosuffixed	tester	tester	1	1.89	79	3.42
vanish	Pseudosuffixed	c	c	2	3.53	57	6.5
cater	Pseudosuffixed	caterer, cat, kitten, holiday	c	1	2.84	44	6.83
caper	Pseudosuffixed	cap, ing, caping	cap	1	4.11	29	6.83
potion	Pseudosuffixed	portion	motion	1	4.68	24	6.36
ponder	Pseudosuffixed	c	pondly	1	2.67	15	6.73
booty	Pseudosuffixed	c	boots	1	3.68	10	6.5
beaker	Pseudosuffixed	bleak	squeak, wrong	1	6.72	5	6.58
stingy	Pseudosuffixed	sting	dk	1	2.68	4	4.75
putty	Pseudosuffixed	c	c	1	4.94	3	4.42
ruby	Pseudosuffixed	c	c	1	5.84	13	3.67
tally	Pseudosuffixed	taller	taller	1	2.5	68	2.55
mutter	Pseudosuffixed	c	but, dk	2	3.61	0	5.33
lotion	Pseudosuffixed	cream	cream, ointment	2	5.32	259	2.83
tailor	Pseudosuffixed	c	c	6	6.26	32	6.5
wander	Pseudosuffixed	wagner, wrong, dk	dk	2	2.95	2	6.5
husky	Pseudosuffixed	hussy	hussy	2	3.16	2	5.42
punish	Pseudosuffixed	punishment	punishment	2	6.21	1	1.67
trillion	Pseudosuffixed	c	dk	2	2.84	0	3.17
tenor	Pseudosuffixed	tender	ten something, or, ten, or	3	4.47	222	4
bully	Pseudosuffixed	c	c	3	4.42	21	6.82
gingerly	Pseudosuffixed	ginger	ginger	5	3.11	5	5.33
rotor	Pseudosuffixed	c	c	4	3.94	8	4.91
legion	Pseudosuffixed	legends	legions	6	3.26	67	6.5
butcher	Pseudosuffixed	butchers	c	5	6.68	1	4.73
analogy	Pseudosuffixed	can't say it	dk	6	1.39	0	1.73
portion	Pseudosuffixed	c	c	12	3.95	26	6
irony	Pseudosuffixed	iron something	iron	13	1.58	71	6.42
mayor	Pseudosuffixed	c	c	16	5.95	824	1.92
fury	Pseudosuffixed	furry	c	16	4.79	20	6.58
temper	Pseudosuffixed	c	c	16	3.11	0	3.82
shower	Pseudosuffixed	c	c	17	6.47	234	3.75
brandy	Pseudosuffixed	c	c	17	6.47	11	3.92
belly	Pseudosuffixed	c	bellows	18	6.53	28	6.67
mission	Pseudosuffixed	miss, sign, gun, war	dk	31	3.63	41	3.58
passion	Pseudosuffixed	dk, can't say	c	32	3.53	100	3.45
billion	Pseudosuffixed	billions	million billion	43	3.79	56	6.25
master	Pseudosuffixed	c	c	40	4.11	3	6.45
forty	Pseudosuffixed	c	c	50	3.79	24	6.25
career	Pseudosuffixed	c	dk	58	2.11	182	3.08

Appendix A (*continued*)

Target	Condition	Response session 1	Response session 2	Word frequency	Word imageability	Stem frequency	Stem imageability
proper	Pseudosuffixed	pellow	pellows, can't say	61	1.58	3	4.75
shoulder	Pseudosuffixed	c	c	71	6.32	772	1.75
brother	Pseudosuffixed	c	c	89	5	2	5.67
corner	Pseudosuffixed	corners	c	105	5.42	25	6.67
study	Pseudosuffixed	student	student	106	4.79	2	5.33
army	Pseudosuffixed	c	c	113	5.58	114	6.67
door	Pseudosuffixed	c	c	347	7	1928	1.75
party	Pseudosuffixed	c	part	377	6.16	487	2.36
million	Pseudosuffixed	c	millions	199	4.05	10	5.58
pastor	Pseudosuffixed	pasta, spaghetti, wrong dk	passion, wrong	4	—	276	2.67
luster	Pseudosuffixed	hustle	dk	0	2.69	10	4.42
manger	Embedded	manager	manager	0	5.22	1012	6.5
lasso	Embedded	c	lassoon	0	5.06	1	5.83
cornea	Embedded	corn, dk	corn something	0	4.78	25	6.67
dingo	Embedded	australian, dingo, dog, hyena	your place, can't say it	0	4.47	0	3.17
legume	Embedded	no idea, leg	legs something	0	4.25	67	6.5
ramble	Embedded	c	c	0	3.58	5	6.75
billow	Embedded	bill, billow, no	bills something	0	3.44	56	6
haggle	Embedded	haggis, wrong	haggis, wrong	0	3.16	1	5.33
blurb	Embedded	c	blob	0	3.06	3	4.24
warble	Embedded	war something	war something	0	2.89	343	5
caret	Embedded	jewel, stone, caret	car something	0	2.6	182	6.82
bungle	Embedded	dk, bun something	bunery	0	2.39	4	6.75
armada	Embedded	arm, dk	arm something, dk	1	5.28	114	6.73
addict	Embedded	adding something	adding	2	4.89	84	2.58
pastel	Embedded	pasta	pale	2	4.21	276	2.67
mayhem	Embedded	c	may, dk	1	4.17	824	2
bellow	Embedded	bellows	c	1	4.05	28	6.58
prowl	Embedded	c	c	1	4	3	4.63
barb	Embedded	barble, fish hook	c	1	3.94	68	6.67
tallow	Embedded	tall, low	tall something	1	2.64	68	5.18
rote	Embedded	rot	rot	1	1.5	8	4.42
millet	Embedded	mill, let, no idea	pets	2	5.22	10	5.92
ripple	Embedded	ripples	ripples	2	5	5	4.67
twitch	Embedded	itching	twickle	3	4.84	1	5.08
riddle	Embedded	c	c	3	2.47	0	1.83
capsule	Embedded	capsules	c	3	6.11	29	6.42
brothel	Embedded	c	brother	3	5.32	2	5.67
doe	Embedded	c	c	3	5.06	1928	1.75
lapse	Embedded	c	c	3	1.89	19	5.25
batch	Embedded	c	c	4	3.22	9	6.58
punch	Embedded	c	c	7	5.16	1	1.92
ribbon	Embedded	c	c	6	7	2	5.33
furnace	Embedded	fur, furren, no idea	fir, but bigger, ferno, dk	6	6.28	20	3.4
rubble	Embedded	c	rubbish	6	4.72	13	4.25
puberty	Embedded	pub something, dk	public	7	3.42	21	6.83
menu	Embedded	c	c	8	6.21	686	6.33
potent	Embedded	pot, tent, no idea	pots, dk	7	2.11	24	6.67
booth	Embedded	c	c	9	5.44	10	6.42
cellar	Embedded	c	c	11	6.11	36	5.58
barley	Embedded	c	c	10	5.26	68	6.67
prophet	Embedded	dk	propet something	11	4.68	6	5.17
push	Embedded	c	c	20	4.16	2	5.58
china	Embedded	c	c	12	6.11	27	6.75
pencil	Embedded	c	c	16	7	19	7
passenger	Embedded	people, customers	c	16	5.42	100	3.17
catch	Embedded	c	c	23	4.47	44	6.83
tackle	Embedded	c	c	22	3.84	2	4.58
portrait	Embedded	c	c	20	6.11	26	5.75
tennis	Embedded	c	c	22	6.37	222	4
studio	Embedded	c	c	22	6.26	2	5.67
crown	Embedded	c	c	23	6.84	2	6.83
temple	Embedded	c	c	25	6.32	0	3.82

(*continued on next page*)

Appendix A (*continued*)

Target	Condition	Response session 1	Response session 2	Word frequency	Word imageability	Stem frequency	Stem imageability
drama	Embedded	actors	dk	22	4.16	1	4.67
soldier	Embedded	c	c	27	6.68	60	2.91
missile	Embedded	missiles	c	28	6.58	41	3.08
partner	Embedded	parners	c	27	4.21	487	2.75
fortune	Embedded	fortunes	c	30	4.37	24	6.75
kitchen	Embedded	cooking, kitchen	c	111	6.68	9	3.36
diet	Embedded	c	c	56	2.4	80	4.2
control	Embedded	trolls	trolls	197	3.2	1	2.2
article	Embedded	artist, art, clothes, furniture	clothes, argyle	41	4.1	166	5.1

Note. c, correct; dk, don't know.

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