This article was downloaded by:[Swets Content Distribution]
On: 26 July 2007
Access Details: [subscription number 768307933]
Publisher: Psychology Press
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Neurocase

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713658146>

Surface Dyslexia in Semantic Dementia: A Comparison of the Influence of Consistency and Regularity

Elizabeth Jefferies^a; Matthew A. Lambon Ralph^a; Roy Jones^b; David Bateman^c; Karalyn Patterson^d

^a University of Manchester, UK

^b Research Institute for the Care of the Elderly, St. Martin's Hospital, Bath, UK

^c Royal United Hospital, Bath, UK

^d MRC Cognition and Brain Sciences Unit, Cambridge, UK

Online Publication Date: 01 August 2004

To cite this Article: Jefferies, Elizabeth, Ralph, Matthew A. Lambon, Jones, Roy, Bateman, David and Patterson, Karalyn (2004) 'Surface Dyslexia in Semantic Dementia: A Comparison of the Influence of Consistency and Regularity',

Neurocase, 10:4, 290 - 299

To link to this article: DOI: 10.1080/13554790490507623

URL: <http://dx.doi.org/10.1080/13554790490507623>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article maybe used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

© Taylor and Francis 2007

Surface Dyslexia in Semantic Dementia: A Comparison of the Influence of Consistency and Regularity

Elizabeth Jefferies¹, Matthew A. Lambon Ralph¹, Roy Jones², David Bateman³ and Karalyn Patterson⁴

¹University of Manchester, UK, ²Research Institute for the Care of the Elderly, St. Martin's Hospital, Bath, UK, ³Royal United Hospital, Bath, UK and ⁴MRC Cognition and Brain Sciences Unit, Cambridge, UK

Abstract

This study addressed the question of exactly which aspects of spelling-sound consistency influence accuracy of reading aloud in surface dyslexic patients with semantic dementia. Oral reading data were obtained from twelve patients on three sets of words that varied in regularity (defined according to grapheme-phoneme correspondences) and consistency (defined according to the pronunciation of word body neighbours). The patients were less accurate for irregular/inconsistent words, which they commonly pronounced in line with sound-spelling regularities, as expected in surface dyslexia. They produced plausible but incorrect responses for some regular as well as many irregular words, suggesting that their reading performance was influenced by sound-spelling relationships not captured by grapheme-phoneme correspondences. On a set of items that varied consistency and regularity independently, the patients showed a large effect of regularity and a smaller but significant effect of consistency in reading aloud. In addition, there was a correlation between degree of semantic impairment and level of reading accuracy for inconsistent items. These findings are discussed in terms of two influential models of reading: the dual-route-cascaded model (Coltheart *et al.*, 2001) and the triangle model (Plaut *et al.*, 1996). It is argued that the triangle model provides a more straightforward account of the relationship between word comprehension and consistency effects in reading.

Introduction

The acquired reading disorder of surface dyslexia is characterised by a relatively preserved ability to read aloud letter strings with predictable spelling-to-sound correspondences but markedly impaired oral reading of words where the pronunciation cannot be inferred from general knowledge of the sound structure of the reader's written language (Behrmann and Bub, 1992; Bub *et al.*, 1985; McCarthy and Warrington, 1986; Patterson and Hodges, 1992; Shallice *et al.*, 1983). Surface dyslexic patients often pronounce irregular words (e.g. PINT) in accordance with their "surface structure" (Marshall and Newcombe, 1973)—that is, in line with their regular orthographic neighbours (MINT, HINT, TINT, etc.). The degree of success/failure on irregular words is also strongly influenced by word frequency.

Two distinct theoretical frameworks can account for this surface dyslexic pattern. In dual-route theories, such as the dual-route cascaded (DRC) model of Coltheart and colleagues (1993; 2001), there are two separate mechanisms for translating orthography into phonology: sublexical conversion based on a series of rules (typically grapheme-phoneme correspondences or GPCs) and lexical lookup of familiar words. Surface dyslexia is interpreted as a frequency-modulated impairment to the lexical procedure—regularisation

errors result from the default operation of the sublexical parsing and conversion mechanism when lexical access fails. This distinction between lexical and sublexical mechanisms has also been advocated by a number of other researchers (e.g. Baluch and Besner, 1991; Marshall and Newcombe, 1973; Paap and Noel, 1991).

An alternative perspective suggests that spelling regularities can be captured by the same system that represents lexical knowledge, eliminating the need for a separate rule-based system (Glushko, 1979; Kay and Marcel, 1981; Seidenberg *et al.*, 1984). The "triangle" model (Plaut *et al.*, 1996; Seidenberg and McClelland, 1989) is a computational instantiation of this approach, which demonstrates that a single mechanism is sufficient to learn the correct pronunciation of both regular and irregular words and to compute appropriate pronunciations of non-words. This model consists of interactive and distributed orthographic and phonological representations and, in Simulation 4 of Plaut *et al.* (1996), an additional source of input to phonology intended to mimic a semantic contribution.

The triangle model can account for surface dyslexics' specific difficulties in reading low frequency exception words because words varying in frequency and spelling to sound

consistency are processed with different degrees of efficiency by the orthography to phonology (O-P) connections (Plaut *et al.*, 1996). High frequency exception words, on which the model was repeatedly trained, have a significant impact on the structure of the O-P pathway, allowing them to be read rapidly and accurately. The O-P pathway can also proficiently read low frequency words with consistent pronunciations, despite its limited exposure to them, because these words benefit from the weights developed to deal with their orthographic neighbours. In contrast, for low frequency inconsistent words, the process of deriving phonology from orthography is insufficiently constrained by the O-P link; the hypothesis is that input to phonology from semantic information about these words assists the network in settling on the correct pattern of phonological activation. Surface dyslexia is interpreted within this framework as a reduction in these semantic constraints.

The triangle framework makes a strong prediction about the involvement of word meaning in reading aloud low frequency exception words; how well does existing evidence support this claim? (1) As noted by Patterson *et al.* (1996), it appears that patients with acquired surface dyslexia are always anomie. This association, though not direct proof of a role for semantics in reading, at least suggests that surface dyslexic patients have a deficit in activating phonology from semantics. (2) The great majority of patients with semantic dementia (SD), who have a specific and progressive decline of semantic memory, are surface dyslexic; this has been demonstrated not only in English-speaking/reading cases (e.g. Parkin, 1993; Patterson and Hodges, 1992) but also in Dutch, (Diesfeldt, 1992), Italian (Rozzini *et al.*, 1997) and Japanese (Fushimi *et al.*, 2003). Although a very few SD patients have been reported who are not surface dyslexic (e.g. Cipolotti and Warrington, 1995), this can be treated in one of two ways. In classical dissociation logic, these cases indicate that the co-occurrence of surface dyslexia with semantic impairment is accidental and therefore uninteresting. In an alternative view, the frequent association, which moreover has a coherent theoretical account, is treated as meaningful, at least as a working hypothesis. Indeed, the triangle framework can accommodate the small number of semantically impaired patients who do not show the surface dyslexic pattern if individual differences in the strengths of the semantic and phonological pathways are taken into account (Plaut, 1997). (3) The onset of semantic impairment in Alzheimer's disease is associated with the emergence of difficulties in reading low frequency exception words (Strain *et al.*, 1998). (4) Several studies have demonstrated an item-specific relationship between semantic impairment and exception word reading: irregular words that individual SD patients still understand relatively well are read more accurately than words that have become semantically degraded (Funnell, 1996; Graham *et al.*, 1994). (5) There is even some evidence of category specificity in surface dyslexia. SD patients comprehend number words relatively well, and they make fewer errors in reading aloud number words with atypical spelling-sound correspondences (e.g. ONE, TWO,

FOUR) than other irregular words of comparable frequency (Butterworth *et al.*, 2001; Jefferies *et al.*, 2004).

This neuropsychological evidence favouring a functional role for word meaning in the computation of O → P for irregular words is augmented by studies of normal single word naming. Strain, Patterson and Seidenberg (1995) reported that a semantic variable, imageability, influenced normal participants' reaction times to read aloud low frequency irregular words but neither high frequency words nor items with consistent spellings. In addition, Rosson (1985) found that the pronunciation of a non-word such as LOUCH could be influenced by a preceding word (e.g. feel) that semantically primed one sound-spelling pattern (touch) rather than another (couch).

Although a semantic contribution to reading aloud (and the consequences of its disruption for irregular words) are strongly predicted by the triangle model and not by dual-route theories, both theoretical frameworks can provide an account of the regularity by frequency interaction that characterises surface dyslexia. The two accounts do, however, make some different assumptions about exactly which aspects of spelling-sound regularities are pertinent in this condition. Dual-route theories predict that surface dyslexic patients should pronounce irregular words in line with a set of GPC rules (although in the more recent versions of the DRC model, the rules can be conditional; see Coltheart *et al.*, 2001). For example, the rule for I is /I/, and therefore surface dyslexics should often pronounce both PINT and BIND with a short /I/. The triangle model alternatively predicts that multiple levels of regularities, including those larger than grapheme-phoneme correspondences, are represented in the connections between orthography and phonology. Consequently, although this framework also predicts frequent errors to PINT (rhyming with MINT and HINT), the O-P pathway even without semantic support should be able to derive the correct pronunciation of irregular words like BIND that are consistent with other similarly spelled words (HIND, MIND, KIND, etc.).

A distinction can therefore be drawn between regularity—whether a pronunciation follows GPC rules, and consistency—whether a pronunciation is typical of orthographically similar words. Although many irregular words are also inconsistent (e.g. PINT vs. MINT, HINT, TINT, etc.), it is possible to find both regular and irregular items that vary in consistency. The triangle model anticipates that (a) surface dyslexics should sometimes mis-read low-frequency, *regular* inconsistent words that have many irregular neighbours (e.g. BEAD vs. HEAD, BREAD, STEAD, etc.); and (b) performance on such regular inconsistent words might actually be worse than that for irregular consistent words like BIND. Dual-route theories apparently make the opposite prediction, anticipating errors to BIND but not BEAD. The present investigation focused on these differing expectations.

Several studies of single word and non-word reading in normal participants have demonstrated an effect of consistency that is independent of regularity (Cortese and Simpson,

2000; Glushko, 1979; Jared, 1997; Jared *et al.*, 1990; Seidenberg *et al.*, 1984), consistent with the triangle model's predictions. To our knowledge, however, very few researchers have attempted to disentangle the impact of consistency vs. regularity in surface dyslexia. Shallice *et al.* (1983) observed a "levels of regularity" effect in patient HTR: "mildly irregular" words (with secondary but relatively common pronunciation patterns) were read more accurately than "very irregular" words (with more unusual spelling-sound correspondences), suggesting that consistency influenced irregular word reading. Similarly, Patterson *et al.* (1996) and Patterson and Behrmann (1997) have reported relative sparing of surface dyslexic patients' ability to read irregular words starting WA- or WO, which form a strong subregularity because the vowel in W words is typically pronounced as in WASH or WORK rather than as in CASH or CORK.

The latest version of the DRC model (Coltheart *et al.*, 2001) incorporates context-dependent GPC rules, an interactive lexical net and cascaded processing; these changes blur the operational differences between the triangle and DRC models and could potentially allow for an effect of consistency in both. Nevertheless, regularity and consistency effects emerge somewhat more inherently from the triangle framework because they are regarded as two ends of a continuum of shared structure, ranging in size from individual phonemes to larger-scale subregularities. In contrast, the two effects are underpinned by different mechanisms in the DRC model. The 2001 DRC model successfully reproduced the impact of consistency observed by Jared (1997), although this outcome arose in the nonlexical pathway as a consequence of the "whammy effect". This occurs when GPC rules, operating in a left to right fashion, trigger the wrong phonology for regular words before the correct activation can be derived (e.g. DROVE → /drov/ before the final "e" is reached). As more of Jared's inconsistent words were "whammied", a stimulus artefact underpinned the consistency effect in the model: it is not clear whether any effect of consistency is anticipated when this factor is controlled.

Cortese and Simpson (2000) compared regularity and consistency effects in human reading latency data with settling times/number of cycles to process the same items in Plaut *et al.*'s (1996) triangle model and Coltheart *et al.*'s (1993) DRC model. They selected a set of words that were either regular or irregular following Coltheart *et al.*'s (1993) GPC rules. These words also varied in consistency, defined as the summed frequencies of word-body neighbours with consistent pronunciations (friends) and inconsistent pronunciations (enemies). For consistent words, the summed frequency of friends was greater than that of enemies ($F > E$) and for inconsistent words, the reverse was true ($E > F$). An equal number of the regular consistent and inconsistent words were subject to the whammy effect. Normal participants showed substantial effects of consistency but only marginal effects of regularity in their reading latencies. This pattern closely matched the performance of Plaut *et al.*'s (1996) triangle model. It did not, however, match Coltheart *et al.*'s (1993)

DRC model, which predicted large effects of regularity and little effect of consistency.

In this study, oral reading data were obtained from 12 SD patients on Cortese and Simpson's (2000) consistency by regularity items and on two other sets of words that manipulated aspects of spelling-sound consistency. According to the triangle model, the SD patients' significant semantic impairments should produce deficits in reading aloud words with inconsistent pronunciations. The DRC model, in contrast, predicts that if these patients have a coincidental surface dyslexia in association with their semantic deficit, they should show strong effects of regularity but not consistency in reading aloud. This case series will also address questions about the relationship between semantic impairment and the size of consistency/regularity effects in reading aloud. The triangle framework predicts a significant correlation between severity of semantic impairment and degree of success/failure to read inconsistent words. The DRC model does not anticipate a clear relationship between semantic impairment and consistency or regularity effects.

Method

Participants

Twelve patients fulfilling criteria for SD (Grossman and Ash, 2004; Hodges *et al.*, 1992; Snowden *et al.*, 1996) were recruited for this study. The patients had presented to memory disorders clinics in either Cambridge or Bath and were unselected on any basis other than their semantic impairment and evidence of temporal-lobe atrophy plus their willingness to take part in a research program (i.e. their reading performance was not criterial). We have omitted individual case descriptions because of the large number of patients in this study and because descriptions of many of these same patients have been published elsewhere (Jefferies *et al.*, [In press]; Jefferies *et al.*, 2004-b; Lambon Ralph *et al.*, 2003; Rogers *et al.*, 2004). Table 1 summarises the patients'

Table 1. Demographic details and neuroimaging results for each patient

Patient	Age	Sex	Education	Neuroimaging
ATe	66	M	19	L>R
MA	64	M	13	L>R
WM	54	F	16	L>R
JCh	58	M	10	L=R
EK	60	F	10	L>R
KH	61	M	11	R>L
KI	65	M	9	Not available
JTw	66	M	11	L>R
GT	71	M	9	L=R
JH	63	F	10	L>R
PD	73	F	9	R>L
MK	67	F	12	L>R

Education column shows years of full-time education (part-time education counted in half years). Neuroimaging column indicates laterality of temporal lobe atrophy.

demographic details and results of structural MR imaging. All scans revealed bilateral temporal lobe atrophy, and the table indicates direction of asymmetry, if any. Note that in this and all subsequent tables giving individual patient data, the 12 patients are ordered on the basis of their scores in a 64-item word-picture matching task, from highest to lowest, as a measure of degree of semantic degradation.

Table 2 provides details of each patient's background neuropsychological assessment. All of the patients presented with a history of gradually worsening semantic impairment, characterised by poor performance on tests requiring comprehension of words and pictures, e.g. word-picture matching and the Pyramids and Palm Trees test (Howard and Patterson, 1992). All patients also revealed word-finding difficulties in spontaneous speech and abnormal performance in picture naming and fluency tasks, although the extent of the anomia varied. Other cognitive domains remained relatively intact. The patients were typically well oriented in time and place and had good day-to-day memory. Their speech was fluent, syntactically well formed and lacking in phonological errors. Their non-verbal reasoning and visual-spatial skills were relatively well preserved, although some of the more severely impaired cases were beginning to show impairments in these domains. As is common in all forms of fronto-temporal dementia, some of the patients' families reported subtle or more striking changes in personality and behaviour.

Materials

The patients were asked to read aloud three sets of words that manipulated different aspects of spelling-sound consistency.

Strain word set. The first word set, devised by Eamon Strain (personal communication), consisted of 120 monosyllabic words, 60 with regular and 60 with irregular spelling-sound correspondences, matched for length (mean = 4.4 letters in both cases). The regular words were marginally more frequent than the irregular words: log frequency (counts per million) = 1.57 (SD = 1.03) and 1.25 (SD = 0.81)

respectively, using measures from Kucera and Francis, 1967; $t(114) = 1.84$, $p = 0.07$; values were unavailable for four items. As semantic degradation in SD is powerfully modulated by concept familiarity/word frequency (Funnell, 1995; Lambon Ralph *et al.*, 1999), the patients' comprehension might have been poorer for the regular words than the irregular words, acting against any predicted effect of regularity on reading. The words were not manipulated according to consistency, but only six of the 60 regular words had an irregular body neighbour. Thus the regular words were in the main consistent as well as regular. The irregular words were typically inconsistent both in terms of GPC rules and body pronunciation.

Cortese word set. This word set consisted of 40 low-frequency monosyllabic words: 20 regular and 20 irregular in terms of GPC rules (Coltheart *et al.*, 1993). Within each of these groups, half of the words were relatively consistent (i.e. the summed frequency of friends exceeded the summed frequency of enemies, $F > E$), and half of the words were relatively inconsistent ($E > F$). The friends and enemies shared the target word's body. The four regularity by consistency word sets were matched for frequency, familiarity, word length, imageability and neighbourhood size (see Cortese and Simpson, 2000, for further methodological details). Mean log frequency (counts per million) was 0.39 for regular $F > E$, 0.72 for regular $E > F$, 0.80 for irregular $F > E$ and 1.06 for irregular $E > F$ (data from Baayen *et al.*, 1993). All but one of the regular words in both the $F > E$ and $E > F$ groups were subject to the whammy effect, either because they contained multi-letter graphemes (e.g. BEAD) or long-distance conditional GPC rules (e.g. PASTE). As consistency was not confounded by the whammy effect in this word set, the DRC model (Coltheart *et al.*, 2001) would apparently not predict a difference in reading for the consistent/inconsistent items.

Gang word set. The third word set consisted of 20 irregular but consistent words. They were called "gang" words after Patterson and Morton (1985) who coined this term to refer to words from body neighbourhoods in which the majority (or

Table 2. Background neuropsychological test scores for each patient

Test	Max	ATe	MA	WM	JCh	EK	KH	KI	JTW	GT	JH	PD	MK	Controls	
														M	SD
Word-picture matching	64	58*	57*	52*	46*	46*	44*	36*	34*	32*	18*	17*	11*	63.7 ^a	0.5 ^a
Naming	64	10*	13*	26*	33*	17*	30*	15*	5*	11*	5*	4*	2*	62.3 ^a	1.6 ^a
PPT: Words ¹	52	44*	43*	39*	36*	36*	41*	35*	31*	32*	25*	26*	33*	51.2 ^a	1.4 ^a
PPT: Pictures ¹	52	47*	40*	44*	40*	35*	35*	31*	35*	37*	37*	26*	26*	51.1 ^a	1.1 ^a
Category fluency	—	17*	15*	30*	20*	31*	15*	27*	9*	24*	12*	7*	1*	113.9 ^b	12.3 ^b
Letter fluency	—	14*	9*	20*	8*	29	NT	17*	17*	24	8*	22	2*	44.2 ^a	11.2 ^a
Coloured Progressive Matrices ²	36	32	28	35	23	33	NT	21	36	35	32	25	22	—	—
Digit span: forwards ³	—	8	6	8	7	6	4*	8	8	6	6	7	5	6.8 ^a	0.9 ^a
Rey figure immediate copy ⁴	36	36	36	36	31	34	36	35	34	34	34	36	30	34.0 ^b	2.9 ^b

The patients are ordered according to their performance on a word-picture matching task that involved selecting a target from a set of ten semantically related items. *denotes abnormal performance. NT = not tested. ¹Pyramids and Palm Trees Test (Howard and Patterson, 1992), ²Raven's Coloured Progressive Matrices (Raven, 1962), ³Wechsler Memory Scale - Revised (Wechsler, 1987), ⁴Rey figure taken from Lezak (1976), ^aControl data from Bozeat *et al.* (2002), ^bControl data from Hodges and Patterson (1995).

even all) of the residents take the same GPC-irregular pronunciation. The 20 items in this set consisted of 10 body-matched pairs, one member of each pair with substantially higher frequency than the other (e.g. LOOK vs. ROOK). Mean log frequency was 1.87 (SD = 0.59) for the high frequency words and 0.17 (SD = 0.56) for the low frequency words (data from Baayen *et al.*, 1993): this difference was highly significant ($t(18) = 6.63$, $p < 0.001$).

Rationale and predictions

The Strain list was employed primarily to establish, on a fairly large set of regular and irregular words, what proportion of these 12 SD cases had reading performance that could be characterised as surface dyslexia. The triangle model predicts that every patient should be surface dyslexic and, furthermore, that performance on irregular words should correlate with degree of semantic deficit. In the DRC model, semantic impairment and surface dyslexia are independent deficits that happen to co-occur in some cases. A secondary purpose of the Strain list was to provide a large enough set of errors to enable analysis of the nature of the incorrect responses to regular as well as irregular words. The Cortese list was administered to evaluate the impact of irregularity vs. inconsistency on the reading performance of these patients. The triangle model predicts a significant effect of both variables; the DRC model predicts that, in those patients who are (coincidental to their semantic dementia) surface dyslexic, regularity should have the major impact on reading. The Gang list was employed as a kind of extreme distinction between the two variables under investigation, in which all of the irregular words came from rather consistent neighbourhoods. Both theoretical frameworks would presumably anticipate better reading of the higher than the lower frequency Gang words. However, the triangle model, unlike the DRC model, also accords a "high impact factor" to neighbourhood consistency and thus might anticipate the ordering Gang high frequency > Gang low frequency > Strain irregular/inconsistent. In contrast, the DRC model might expect better accuracy

for the Strain irregular than the Gang low frequency words, in line with their significantly higher frequency ($t(65) = 4.03$, $p < 0.001$).

Testing procedure

Items from the three sets above were pooled and presented to every patient in a fixed random order. The words were printed in lower-case letters in a large font and were presented one at a time. The patients were asked to read each item aloud. No time pressure was imposed, and reaction times were not measured.

Results

Effects of regularity and consistency on reading accuracy

Table 3 shows individual patient scores and the mean percentage of words read correctly in each experimental condition.

Strain word set. As a group, the patients showed a highly reliable difference in reading accuracy between regular and irregular words ($t(11) = 9.61$, $p < 0.0001$ by subjects, $t(118) = 6.80$, $p < 0.0001$ by items). Eleven of the 12 patients as individuals also had a significant advantage in reading accuracy for the regular compared to the irregular words (range: $\chi^2(1) = 5.84$, $p < 0.05$ to $\chi^2(1) = 26.19$, $p < 0.0001$). The advantage for one patient, KH, was in the right direction but small and not significant ($\chi^2(1) < 1$). It is perhaps worth noting that although KH's accuracy does not convincingly fit a surface dyslexic profile, 70% of his errors to the irregular Strain words were regularisations or other LARC errors (see below).

Cortese word set. A within-subjects analysis of variance (ANOVA) was used to examine the influence of consistency and regularity on reading accuracy in the Cortese word set, in which these factors were varied independently. There were significant main effects of both consistency ($F(1, 11) = 6.38$, $p < 0.05$) and regularity ($F(1, 11) = 15.75$, $p < 0.01$) and no

Table 3. Reading accuracy for individual patients as a function of regularity and consistency

Set	Condition	ATe	MA	WM	JCh	EK	KH	KI	JTw	GT	JH	PD	MK	M	SD
Strain	Regular/consistent (N = 60)	97	95	92	93	88	72	85	65	98	58	97	87	85.6	12.8
Strain	Irregular/inconsistent (N = 60)	55	78	68	70	57	67	57	35	73	23	65	48	58.1	15.4
Cortese	Regular, consistent (N = 10)	90	80	100	70	70	70	80	60	90	70	90	90	80.0	11.5
Cortese	Regular, inconsistent (N = 10)	80	100	90	70	60	70	70	30	70	60	90	50	70.0	18.3
Cortese	Irregular, consistent (N = 10)	60	80	50	50	80	60	60	40	100	20	80	80	63.3	20.9
Cortese	Irregular, inconsistent (N = 10)	70	80	30	50	50	50	40	40	70	40	60	20	50.0	16.8
Cortese	Consistent (N = 20)	75	80	75	60	75	65	70	50	95	45	85	85	71.7	14.0
Cortese	Inconsistent (N = 20)	75	90	60	60	55	60	55	35	70	50	75	35	60.0	15.4
Cortese	Regular (N = 20)	85	90	95	70	65	70	75	45	80	65	90	70	75.0	13.4
Cortese	Irregular (N = 20)	65	80	40	50	65	55	50	40	85	30	70	50	56.7	16.0
Gang	Higher frequency (N = 10)	90	100	100	90	100	90	100	70	100	50	90	90	89.2	14.4
Gang	Lower frequency (N = 10)	70	90	80	70	60	80	60	50	90	40	70	50	67.5	15.3

Figures indicate percentage of words read correctly.

significant interaction between them ($F(1, 11) < 1$). The same data were additionally examined in a by-items analysis, which yielded a significant effect of regularity ($F(1, 36) = 7.22$, $p < 0.05$), an effect of consistency that approached significance ($F(1, 36) = 2.93$, $p < 0.1$) and no significant interaction ($F(1, 36) < 1$).

Relatively few individual patients' data revealed significant effects of either consistency or regularity, as the number of items per condition in this set was small. Only four individual contrasts were statistically reliable or nearly so: MK consistent $\gg$ inconsistent words ($\chi^2(1) = 8.44$, $p < 0.01$); WM regular $\gg$ irregular words ($\chi^2(1) = 11.40$, $p < 0.001$); GT consistent $>$ inconsistent ($\chi^2(1) = 2.77$, $p < 0.1$); JH regular $>$ irregular ($\chi^2(1) = 3.61$, $p = 0.06$).

Gang word set. Reading accuracy was significantly better for the higher frequency items in the Gang list, whether analysed by subjects ($t(11) = 6.29$, $p < 0.0001$) or by items ($t(18) = 2.81$, $p < 0.05$). Again, the number of items in this set was small, and consequently, none of the patients showed a significant advantage for high over low frequency Gang words in their individual data, though the difference approached significance for two patients, KI and EK (both $\chi^2(1) = 2.81$, $p = 0.09$).

As noted above, a contrast between the Strain irregular words and the Gang words enables an informal comparison of the impact of frequency and consistency on irregular word reading. These word subsets, coming from different lists, were not carefully matched, but they consisted of monosyllabic words of between 4–6 letters in length and all irregular by GPC criteria. According to a dual-route model, frequency should be the main predictor of success on such irregular words, yielding the order Strain = Gang high frequency $>$ Gang low frequency. If consistency is also an influential predictor, as in the triangle model, then one might in fact anticipate Gang high frequency $>$ Gang low frequency $>$ Strain irregular. Percentages of correct reading for these three subsets were Gang high 89% $\gg$ Gang low 68% $>$ Strain 58%. The advantage for Gang-high relative to Strain words was reliable by subjects ($t(11) = 12.71$, $p < 0.0001$) and by items ($t(68) = 3.41$, $p < 0.01$). The advantage for Gang-low over Strain items was significant by subjects ($t(11) = 5.20$, $p < 0.001$) but not by items ($t(68) < 1$).

Discussion. In this group of SD patients with surface dyslexia, both regularity and consistency influenced reading accuracy. This pattern differs somewhat from the performance of both the triangle and the DRC models in Cortese and Simpson's (2000) simulations using the same items: the triangle model showed strong effects of consistency but not regularity, whereas the DRC model showed strong effects of regularity but not consistency (the consistency by regularity interaction was not significant for either model). The DRC model does not appear to be compatible with the significant effect of consistency obtained in our study, given that factors affecting the GPC route (by which the patients were supposedly reading) were controlled in the Cortese materials, including regularity and the whammy effect. Nevertheless,

the triangle model needs to explain why the patients showed substantial effects of regularity in reading aloud, even when consistency was controlled. As noted in the Introduction, this standpoint might expect some impact of regularity on reading accuracy, given that regularity and consistency are regarded as two ends of a continuum of shared structure, ranging in size from individual phonemes to larger-scale subregularities. However, we found that lower-level regularities (at the level of grapheme to phoneme correspondences) played a larger role than word-body consistency in reading: in contrast, in healthy participants, the opposite appears to be true (Cortese and Simpson, 2000; Jared, 1997). We will return to this point in the General Discussion.

Correlations between reading performance and degree of semantic impairment

Table 4 shows the correlation between semantic impairment (as measured by word-picture matching performance) and reading accuracy for each word set across the 12 patients. In general, the correlations approached significance for inconsistent/irregular words but not for their consistent/regular counterparts, in line with the suggestion that semantics plays a more important role in translating from orthography to phonology for words with atypical spelling to sound relationships. It should, of course, be noted that the somewhat smaller range of scores in consistent/regular word reading offers lower potential for significant correlations.

Within the Cortese word set, the correlation between reading accuracy and the degree of semantic impairment was much higher for inconsistent than for irregular words, in line with the proposal that the reading system is sensitive to regularities that go beyond GPC rules. The correlations between comprehension (word-picture matching) and reading of inconsistent words were not strikingly high, accounting in general for only about 25% of the variance. Nevertheless, given how many other factors undoubtedly contribute to

Table 4. Correlations between reading accuracy and severity of semantic impairment

Experimental set	Condition	Correlation with word-picture matching (mean = 37.3, SD = 15.7, max = 64)
Strain	Regular/consistent	.35
Strain	Irregular/inconsistent	.50 ($p < .05$)
Cortese	Regular, consistent	.01
Cortese	Regular, inconsistent	.44 ($p = .08$)
Cortese	Irregular, consistent	.01
Cortese	Irregular, inconsistent	.47 ($p = .06$)
Cortese	Consistent	.01
Cortese	Inconsistent	.52 ($p < .05$)
Cortese	Regular	.31
Cortese	Irregular	.25
Gang	High frequency	.46 ($p = .07$)
Gang	Low frequency	.57 ($p < .05$)

$p > .1$ unless otherwise stated. Significance levels are for one-tailed tests.

success on both the comprehension measure (e.g. factors such as picture processing) and reading aloud (e.g. factors such as phonological processing) and that the words in the reading tests and the comprehension test were entirely different, it does seem noteworthy that all three sets of inconsistent words yielded correlations of at least 0.40 with an assessment of semantic knowledge. There was also a significant correlation between word-picture matching and reading accuracy for the consistent/irregular Gang words, suggesting that irregular word reading is not immune from the effects of semantic degradation, even for items bolstered by a G gang.

Discussion. The presence of a correlation between the severity of semantic impairment and inconsistent/irregular word reading provides strong support for the triangle model. In contrast, the DRC model treats surface dyslexia and semantic impairment as coincidental. Both inconsistent regular words (Cortese set) and consistent irregular words (Gang set) showed this relationship. Although the triangle framework envisages a stronger impact of semantic impairment on word-body consistency than GPC regularity, both effects are thought to be underpinned by the same mechanism; consequently, it might be expected that semantics would correlate with reading accuracy for both inconsistent/irregular words, especially if lower-level regularities play an enlarged role in the reading of SD patients.

Reading errors

The error type usually highlighted in surface dyslexia is a “regularised” reading, in which an irregular word is pronounced in line with the major correspondences described by Venezky (1970); for example, SEW read as “sue” and TON pronounced to rhyme with “on”. An alternative and broader term for such errors is LARC (Legitimate Alternative Reading of Components, Patterson *et al.*, 1995): LARC errors need not be pure regularisations but are nevertheless plausible or legitimate responses in the sense that the pronuncia-

tion of one or more components, although incorrect in this context, would be appropriate in other words sharing those components; in English, they include the minor as well as the major correspondences described by Venezky (1970). LARC responses can occur for both regular and irregular words; examples of such errors for regular words are HOOT pronounced to rhyme with “foot” and MOUSE read as “moose”; examples for irregular words are BLOOD pronounced to rhyme with “good” and SWEAT to rhyme with “great”. Furthermore, some responses clearly reflect a degree of regularising or “LARC-ing” but deviate from a perfectly legitimate alternative reading, as in BLOOD → “bloo” or DOUGH → “dowdge”. We combined errors of these three types into a single LARC error category. Remaining incorrect readings were assigned to one of two groups: (1) “Other” errors were implausible pronunciations of the letter string. This category included a number of errors that apparently resulted from letter misidentifications (a phenomenon that is increasingly recognised to occur in SD, especially as the condition worsens: Cumming *et al.*, 2004; Graham *et al.*, 2001; Grossman and Ash, 2004; Hodges *et al.*, 1992); examples of such errors are KEG → “ked” and SOB → “sop”. Other “other” errors included the addition or deletion of letters/sounds (e.g. TRUMP → “strump”) and other non-plausible pronunciations (e.g. MOULD → “mald”, STACK → “stacked”). (2) Omission errors were a failure to respond. The percentage of errors in each of these categories is shown for each condition in Table 5.

Strain word set. Pure regularisations made a substantial contribution to the patients’ poorer performance on irregular words, accounting for an average of 49% of all errors on these items (range 17% to 68%). However, the patients also made frequent LARC errors on both irregular and regular words. An average of 83% of errors on irregular words (range 33% to 95%) and 52% of errors on regular words (range 25% to 100%) were phonologically plausible readings. This finding that LARC errors occurred frequently for regular as well as

Table 5. The mean number of errors of different types as a function of regularity and consistency

Set	Condition	Max*	Regularisation		Total LARC		Other		Omission	
			M	SD	M	SD	M	SD	M	SD
Strain	Regular/consistent	14.3	–	–	7.4	6.9	6.4	7.3	0.6	1.5
Strain	Irregular/inconsistent	41.8	20.6	9.6	34.9	15.9	5.3	4.1	1.7	5.3
Cortese	Regular, consistent	20.0	–	–	14.2	9.0	5.8	5.1	0.0	0.0
Cortese	Regular, inconsistent	30.0	–	–	20.0	12.1	9.2	10.8	0.8	2.9
Cortese	Irregular, consistent	36.7	11.7	9.4	25.0	16.8	8.3	10.3	3.3	8.9
Cortese	Irregular, inconsistent	50.0	25.0	15.1	40.0	20.4	5.0	5.2	5.0	14.5
Cortese	Consistent	28.3	5.8	4.7	19.6	9.6	7.1	7.2	1.7	4.4
Cortese	Inconsistent	40.0	12.5	7.5	30.0	13.3	7.1	7.5	2.9	8.6
Cortese	Regular	25.0	–	–	17.1	8.9	7.5	6.9	0.4	1.4
Cortese	Irregular	43.3	18.3	10.5	32.5	16.2	6.7	6.9	4.2	11.6
Gang	Higher frequency	10.8	2.5	4.5	6.7	9.8	3.3	6.5	0.8	2.9
Gang	Lower frequency	32.5	16.7	15.0	26.7	17.2	4.2	6.7	1.7	5.8

Errors of each type shown as a percentage of the total number of items presented. *Maximum column denotes percentage of incorrect responses overall. LARC = legitimate alternative reading of components. Total LARC column includes regularisations, LARC errors and mixed errors.

irregular words, which is a strong prediction of the triangle framework, indicates that reading aloud is sensitive to sound-spelling consistencies that extend beyond the level of simple one-to-one GPC rules.

Cortese word set. A repeated-measures ANOVA was used to examine the effect of consistency and regularity on the total number of phonologically plausible errors. A larger number of such errors occurred both for irregular words relative to regular (by subjects: $F(1, 11) = 8.43, p < 0.05$; by items: $F(1, 36) = 5.09, p < 0.05$) and for inconsistent words relative to consistent (by subjects: $F(1, 11) = 6.59, p < 0.05$; by items: $F(1, 36) = 2.30, n.s.$). In addition, there was a significant interaction between consistency and regularity (by subjects: $F(1, 11) = 5.30, p < 0.05$; by items: $F(1, 36) = 3.03, n.s.$). Bonferroni t tests indicated that consistency had a significant effect on the total number of LARC errors for irregular words ($t(11) = 2.76, p < 0.05$) but not for regular words ($t(11) = 1.74, n.s.$).

Gang word set. Significantly fewer phonologically plausible errors occurred for the irregular but highly consistent Gang words (collapsing across the two frequency groups) than for the irregular and inconsistent Strain words (by subjects: $t(11) = 8.68, p < 0.0001$; by items: $t(78) = 2.84, p < 0.01$) despite the fact that the Strain words were more frequent. Word frequency had a significant effect on the occurrence of LARC errors within the Gang set (by subjects: $t(11) = 6.63, p < 0.0001$; by items: $t(18) = 2.63, p < 0.05$).

In summary, these results indicate that 1) frequent LARC errors occur on regular as well as irregular words and 2) the occurrence of LARC errors is influenced by both consistency and regularity. The triangle framework offers a straightforward account of both of these findings.

General Discussion

This study addressed the question of exactly which aspects of spelling-sound consistency influence reading accuracy in patients with semantic dementia. Oral reading data were obtained from twelve SD patients on three sets of words that varied in regularity (defined according to GPC rules) and consistency (defined according to the pronunciations of orthographic neighbours). The study also contributed to evidence suggesting that success in translating orthography to phonology is modulated by semantic knowledge. Our main findings are summarised below.

1. On a relatively large set of items that varied in consistency/regularity (but did not manipulate these two factors independently), the SD patients were markedly impaired at reading irregular/inconsistent words. In contrast, their reading of regular/consistent words was relatively well preserved.
2. The patients made frequent LARC errors in their reading of both regular and irregular words. Pure regularisation errors, which are a subset of LARC errors, cannot by definition occur to regular words; but in a written language like English with a complex set of relations between spelling

and sound, many regular words as well as all irregular words permit incorrect but plausible pronunciations—plausible because the pronunciation assigned to a letter or group of letters is incorrect for the target word but correct in a different context. LARC errors thus reflect a broad range of knowledge of spelling-sound correspondences and certainly indicate, if further indication is necessary, that there is no such thing as a simple dichotomy between regular and irregular words.

3. On a set of items that varied regularity and consistency independently (the set from Cortese and Simpson, 2000), the SD patients showed a large effect of regularity and a smaller but significant effect of consistency. The same pattern of incorrect but plausible pronunciations characterised both the consistency and regularity effects, in line with the view that they result from a single mechanism. These findings corroborate previous studies demonstrating that both normal participants (Cortese and Simpson, 2000; Glushko, 1979; Jared, 1997; Jared *et al.*, 1990; Seidenberg *et al.*, 1984; Treiman *et al.*, 1995) and patients with surface dyslexia (Fushimi *et al.*, 2003; Patterson and Behrmann, 1997; Shallice *et al.*, 1983) are sensitive to graded effects of consistency in single word naming.
4. An informal indication of the power of consistency was the patients' performance in reading irregular words from "Gang" neighbourhoods where most or all of the neighbourhood residents have the same irregular spelling-sound relationship. By no means could it be claimed that the patients were normal at reading these Gang-irregular words, but they achieved a higher rate of success on them than on even higher frequency irregular words not bolstered by a Gang.
5. Finally, word-picture matching performance, which provides one simple index of the degree of semantic impairment, was correlated with reading accuracy for inconsistent words, and in the case of the Gang items, also consistent but irregular words. There was no correlation between semantic impairment and reading accuracy for the other subsets of regular and consistent words, suggesting that the ability to compute correct pronunciations of these items is not significantly altered by degraded semantic representations. This association between semantic deficits and surface dyslexia is in line with several earlier findings (Graham *et al.*, 1994; Patterson and Hodges, 1992; Strain *et al.*, 1998).

These findings of an effect of consistency on reading accuracy in SD and a correlation between semantic impairment and inconsistent word reading are straightforward predictions of the triangle model (Plaut *et al.*, 1996; Seidenberg and McClelland, 1989). This model proposes that the link between orthography and phonology is not sufficient for accurate oral reading of lower frequency inconsistent words, as they derive little support from similarities with other items. Consequently, semantic constraints contribute positively to the network's ability to settle on the correct pattern of phonological activation for inconsistent words. It is not entirely clear how the DRC model (Coltheart *et al.*, 1993; Coltheart *et al.*,

2001) could account for these findings. Although consistency effects might be produced within the lexical route of the DRC model (Coltheart *et al.*, 1993), the 1993 version of this model did not show significant effects of consistency on settling times for the items used in the current study (Cortese and Simpson, 2000). The more recent version of the DRC model (Coltheart *et al.*, 2001) did successfully reproduce Jared's (1997) consistency results, but the effect arose in the GPC route as a result of a stimulus artefact that was also purported to account for Jared's findings. In addition, the model does not predict a correlation between semantic impairment and deficits in inconsistent word reading. The DRC model has a separate semantic reading route but it is not thought to play much of a role in single-word oral reading. Surface dyslexia has been simulated by lesioning the orthographic input lexicon, which is a component of the non-semantic lexical route (Coltheart *et al.*, 2001). Consequently, SD patients' semantic impairments and surface dyslexia are seen as resulting from damage to two separate systems in neighbouring brain areas, rather than having a common cause, making it difficult to account for item-specific associations (e.g. the results of Butterworth *et al.*, 2001, Funnell, 1996, and Graham *et al.*, 1994). For these reasons, the triangle model appears to offer a more straightforward and parsimonious account of the relationship between semantics and reading accuracy for inconsistent words.

It should be acknowledged that the SD patients in the current study showed larger effects of regularity than consistency on the Cortese word set, which included independent manipulations of these two factors. In contrast, Cortese and Simpson's (2000) normal participants, who were tested on the same items, showed larger effects of consistency than regularity in their reading latencies (also see Jared, 1997, for a comparable finding). Cortese and Simpson (2000) argued that in experiments using only real words, "consistency effects should be and always are larger than regularity effects" (p. 1273). This prediction does not appear to hold true for these SD patients.

One intriguing possibility germane to this discrepancy is that SD patients may be less influenced by word body consistency than normal participants because the patients have degraded representations of some of the stimulus words' friends/enemies. For example, an inconsistent word like TOAD might be relatively unaffected by the existence of the unfriendly neighbour BROAD if the correct phonological representation for "broad" failed to be activated to a normal degree. Lower-level consistency effects, which are effectively mappings between individual graphemes and phonemes (e.g. I to /I/), may become more central in reading aloud for SD patients, given that sound-spelling mappings are likely to follow these patterns in the majority of words that are retained. If this is the case, SD patients might be expected to show stronger consistency effects for items with a smaller number of higher frequency friends/enemies compared with those with a larger number of lower frequency friends/enemies, as high frequency words and concepts are typically

more preserved in this condition (Funnell, 1995). Normal participants, in contrast, should perform equivalently on the two sets of words because their consistency is comparable in terms of the summed frequencies of friends/enemies (Jared *et al.*, 1990). Unfortunately, in the present study, there were insufficient items to allow a rigorous examination of this issue.

It has been argued that normal participants show stronger effects of regularity than consistency in non-word reading, in contrast with their word reading performance. For example, Andrews and Scarrett (1998) reported that healthy people usually pronounced non-words in line with GPC rules, rather than in line with their word body neighbours. This was also the case for non-words containing the same bodies as the Cortese words examined here (Cortese and Simpson, 2000; using data from Seidenberg *et al.*, 1994). In this way, our SD patients' word reading apparently resembles healthy participants' non-word reading. This ostensible difference between word and non-word performance in normal subjects remains controversial and is not fully understood. Nevertheless, it may prove relevant in accounting for the balance of regularity/consistency effects observed in SD.

Our finding of a small but significant consistency effect, together with a larger effect of regularity and a correlation between semantic impairment and inconsistent word reading in SD, is compatible with the view that consistency and regularity have a common underlying mechanism. In line with the predictions of the triangle model, semantic representations apparently play an important role in correct reading aloud of irregular and inconsistent words that are not able to benefit from shared structure in the orthography to phonology pathway. This shared structure ranges in scale from individual phoneme-grapheme correspondences to larger word body consistencies. Questions remain, however, about the extent to which different levels of consistencies come into play for normal participants and SD patients during word and non-word reading.

Acknowledgments

This work was carried out in part while the first author was on a study visit to the MRC Cognition and Brain Sciences Unit, Cambridge, UK, funded by the Experimental Psychology Society. The work was also supported by a grant from the NIMH (MH64445). We are very grateful to Michael Cortese for permission to use his stimulus materials and for his many helpful comments on this work. We would also like to thank John Hodges, Addenbrooke's Hospital, Cambridge, for referring some of the patients to us.

References

- Andrews S, Scarrett DR. Rule and analogy mechanisms in reading nonwords: Hough dou peapel rede gnew wirds? *Journal of Experimental Psychology: Human Perception and Performance* 1998; 24: 1052–86.

- Baayen RH, Piepenbrock R, van Rijn H. The CELEX Lexical Database [CD-ROM]. Philadelphia, PA: Linguistic Data Consortium, University of Pennsylvania, 1993.
- Baluch B, Besner D. Visual word recognition: Evidence for strategic control of lexical and nonlexical routines in oral reading. *Journal of Experimental Psychology: Learning, Memory and Cognition* 1991; 17: 644–52.
- Behrmann M, Bub D. Surface dyslexia and dysgraphia: Dual routes, single lexicon. *Cognitive Neuropsychology* 1992; 9: 209–51.
- Bozeat S, Lambon Ralph MA, Patterson K, Hodges JR. The influence of personal familiarity and context on object use in semantic dementia. *Neurocase* 2002; 8: 127–34.
- Bub D, Cancelliere A, Kertesz A. Whole-word and analytic translation of spelling to sound in a nonsemantic reader. In: Coltheart M, editor. *Surface dyslexia*. Hillsdale, NJ: Erlbaum, 1985: 15–34.
- Butterworth B, Cappelletti M, Kopelman M. Category specificity in reading and writing: The case of number words. *Nature Neuroscience* 2001; 4: 784–86.
- Cipolotti L, Warrington EK. Semantic memory and reading abilities: A case report. *Journal of the International Neuropsychological Society* 1995; 1: 104–10.
- Coltheart M, Curtis B, Atkins P, Haller M. Models of reading aloud: Dual route and parallel distributed processing approaches. *Psychological Review* 1993; 100: 589–608.
- Coltheart M, Rastle K, Perry C, Langdon R, Ziegler J. DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review* 2001; 108: 204–56.
- Cortese MJ, Simpson GB. Regularity effects in word naming: What are they? *Memory and Cognition* 2000; 28: 1269–76.
- Cumming T, Graham KS, Patterson K. One bird with two stones: Letter-by-letter reading in pure alexia and semantic dementia. *Cognitive Neuroscience Society*. San Francisco, 2004.
- Diesfeldt HFA. Impaired and preserved semantic memory functions in dementia. In: Backman L, editor. *Memory functioning in dementia*. Amsterdam: Elsevier, 1992: 227–63.
- Funnell E. Objects and properties: A study of the breakdown of semantic memory. *Memory* 1995; 3: 497–518.
- Funnell E. Response biases in oral reading: An account of the co-occurrence of surface dyslexia and semantic dementia. *Quarterly Journal of Experimental Psychology* 1996; 49A: 417–46.
- Fushimi T, Komori K, Ikeda M, Patterson K, Ijuin M, Tanabe H. Surface dyslexia in a Japanese patient with semantic dementia: Evidence for similarity-based orthography-to-phonology translation. *Neuropsychologia* 2003; 41: 1644–58.
- Glushko RJ. The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance* 1979; 5: 674–91.
- Graham KS, Hodges JR, Patterson K. The relationship between comprehension and oral reading in progressive fluent aphasia. *Neuropsychologia* 1994; 32: 299–316.
- Graham NL, Patterson K, Hodges JR. The emergence of jargon in progressive fluent dysgraphia: The widening gap between target and response. *Cognitive Neuropsychology* 2001; 18: 343–61.
- Grossman M, Ash S. Primary progressive aphasia: A review. *Neurocase* 2004; 10: 3–18.
- Hodges JR, Patterson K. Is semantic memory consistently impaired early in the course of Alzheimer's disease? Neuroanatomical and diagnostic implications. *Neuropsychologia* 1995; 33: 441–59.
- Hodges JR, Patterson K, Oxbury S, Funnell E. Semantic dementia: Progressive fluent aphasia with temporal lobe atrophy. *Brain* 1992; 115: 1783–1806.
- Howard D, Patterson K. *Pyramids and Palm Trees: A test of semantic access from pictures and words*. Bury St. Edmunds, Suffolk: Thames Valley Test Company, 1992.
- Jared D. Spelling-sound consistency affects the naming of high-frequency words. *Journal of Memory and Language* 1997; 36: 505–29.
- Jared D, McRae K, Seidenberg MS. The basis of consistency effects in word naming. *Journal of Memory and Language* 1990; 29: 687–715.
- Jefferies E, Jones R, Bateman D, Lambon Ralph MA. A semantic contribution to nonword recall? Evidence for intact phonological processes in semantic dementia. *Cognitive Neuropsychology In press*.
- Jefferies E, Jones R, Bateman D, Lambon Ralph MA. When does word meaning affect immediate serial recall in semantic dementia? *Cognitive, Affective and Behavioral Neuroscience* 2004-b; 4: 20–42.
- Jefferies E, Patterson K, Jones RW, Bateman D, Lambon Ralph MA. A category-specific advantage for numbers in verbal short-term memory: Evidence from semantic dementia. *Neuropsychologia* 2004-a; 42: 639–60.
- Kay J, Marcel AJ. One process, not two, in reading aloud: Lexical analogies do the work of nonlexical rules. *Quarterly Journal of Experimental Psychology* 1981; 33A: 397–414.
- Lambon Ralph MA, Graham KS, Patterson K, Hodges JR. Is a picture worth a thousand words? Evidence from concept definitions by patients with semantic dementia. *Brain and Language* 1999; 70: 309–35.
- Lambon Ralph MA, Patterson K, Garrard P, Hodges JR. Semantic dementia with category specificity: A comparative case-series study. *Cognitive Neuropsychology* 2003; 20: 307–26.
- Lezak M. *Neuropsychological assessment*. New York: Oxford University Press, 1976.
- Marshall JC, Newcombe F. Patterns of paralexia: A psycholinguistic approach. *Journal of Psycholinguistic Research* 1973; 2: 175–99.
- McCarthy R, Warrington EK. Phonological reading: Phenomena and paradoxes. *Cortex* 1986; 22: 359–80.
- Paap KR, Noel RW. Dual route models of print to sound: Still a good horse race. *Psycholinguistic Research* 1991; 53: 13–24.
- Parkin AJ. Progressive aphasia without dementia: A clinical and cognitive neuropsychological analysis. *Brain and Language* 1993; 44: 201–20.
- Patterson K, Behrmann M. Frequency and consistency effects in a pure surface dyslexic patient. *Journal of Experimental Psychology: Human Perception and Performance* 1997; 23: 1217–31.
- Patterson K, Hodges JR. Deterioration of word meaning: Implications for reading. *Neuropsychologia* 1992; 30: 1025–40.
- Patterson K, Morton J. From orthography to phonology: An attempt at an old interpretation. In: Patterson KE, Marshall JC, Coltheart M, editors. *Surface dyslexia*. London: Lawrence Erlbaum, 1985: 335–59.
- Patterson K, Plaut DC, McClelland JL, Seidenberg MS, Behrmann M, Hodges JR. Connections and disconnections: A connectionist account of surface dyslexia. In: Ruppel E, editor. *Neural modelling of cognitive and brain disorders*. Singapore: World Scientific, 1996: 177–99.
- Patterson K, Suzuki T, Wydell T, Sasanuma S. Progressive aphasia and surface alexia in Japanese. *Neurocase* 1995; 1: 115–65.
- Plaut D, McClelland JL, Seidenberg M, Patterson K. Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review* 1996; 103: 56–115.
- Plaut DC. Structure and function in the lexical system: Insights from distributed models of word reading and lexical decision. *Language and Cognitive Processes* 1997; 12: 765–805.
- Raven JC. *Coloured progressive matrices sets A, AB, B*. London: H. K. Lewis, 1962.
- Rogers TT, Lambon Ralph MA, Hodges JR, Patterson K. Natural selection: The impact of semantic impairment on lexical and object decision. *Cognitive Neuropsychology* 2004; 21: 331–52.
- Rossen, MB. The interaction of pronunciation rules and lexical representations in reading aloud. *Memory and Cognition* 1985; 13: 90–99.
- Rozzini L, Bianchetti A, Lussignoli G, Cappa S, Trabucchi M. Surface dyslexia in an Italian patient with semantic dementia. *Neurocase* 1997; 3: 307–12.
- Seidenberg MS, McClelland JL. A distributed, developmental model of word recognition and naming. *Psychological Review* 1989; 96: 523–68.
- Seidenberg MS, Plaut DC, Petersen AS, McClelland JL, McRae K. Nonword pronunciation and models of word recognition. *Journal of Experimental Psychology: Human Perception and Performance* 1994; 20: 1177–96.
- Seidenberg MS, Waters GS, Barnes MA, Tanenhaus MK. When does irregular spelling or pronunciation influence word recognition? *Journal of Verbal Learning and Verbal Behavior* 1984; 23: 383–404.
- Shallice T, Warrington EK, McCarthy R. Reading without semantics. *Quarterly Journal of Experimental Psychology* 35A: 1983; 111–38.
- Snowden JS, Neary D, Mann DMA, editors. *Frontotemporal lobar degeneration: Frontotemporal dementia, progressive aphasia, semantic dementia*. London: Churchill Livingstone, 1996.
- Strain E, Patterson K, Graham N, Hodges JR. Word reading in Alzheimer's disease: Cross-sectional and longitudinal analyses of response time and accuracy data. *Neuropsychologia* 1998; 36: 115–71.
- Strain E, Patterson K, Seidenberg MS. Semantic effects in single-word naming. *Journal of Experimental Psychology: Learning, Memory and Cognition* 1995; 21: 1140–54.
- Treiman R, Mullennix J, Bijeljac-Babic R, Richmond-Welty ED. The special role of rimes in the description, use and acquisition of English orthography. *Journal of Experimental Psychology: General* 1995; 124: 107–36.
- Venezky RL. *The structure of English orthography*. The Hague, The Netherlands: Mouton, 1970.
- Wechsler D. *Wechsler Memory Scale—Revised (WMS-R)*. New York: Psychological Corporation, 1987.