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Gabriele Miceli

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Morphological errors and the representation of morphology in the lexical–semantic system

GABRIELE MICELI

Istituto di Neurologia, Università Cattolica, Roma, IRCCS S. Lucia, Largo A. Gemelli 8, 00168 Rome, Italy

SUMMARY

Neuropsychological studies support the hypothesis that morphology is represented autonomously, both at the level of word meaning and at the level of word form. In output processes, morphologically organized semantic information activates lexical representations of roots and affixes, which are composed before production. In input processes, the stimulus is parsed along the morphological dimension, to access root and affix lexical representations, which in turn activate morphologically organized semantic information. Inflectional and derivational morphology are represented independently in the lexicon. Inflected words are fully decomposed; derived words are decomposed into base form + inflection. In aphasia, morphological errors in transcoding tasks always co-occur with semantic and/or phonemic errors. Morphological errors in transcoding tasks require combined damage to morphological representations in the semantic–lexical system and to sublexical conversion procedures; they co-occur with semantic errors when also root representations are damaged. The co-occurrence of morphological and phonemic errors can be accounted for by several hypotheses, but its theoretical meaning is still uncertain.

1. INTRODUCTION

Neuropsychological evidence has been used to propose hypotheses on the organization of the different types of knowledge involved in word processing. One current model is schematized in figure 1. According to this hypothesis, word meaning and word form are represented independently – in the semantic and in the lexical component of the semantic–lexical system, respectively. The semantic component is unitary and supramodal (but for a different view, see Shallice (1993), whereas the lexicon has several, modality-specific subcomponents. The model assumes that input and output subcomponents of the lexicon are independent†, and that knowledge of phonological form is represented autonomously from knowledge of orthographic form. In word production, representations in the output lexicons are activated by different mechanisms, depending on task demands.

In object naming, semantic information activates the correct output lexical representation above threshold, and other lexical representations to a lesser degree that is proportional to the semantic similarity between the to-be-named word and meaning-related entries. For example, the picture of a tulip activates *tulip* above threshold, and also activates *rose* and *Holland*, but not enough for production (Caramazza & Hillis 1990). An intact semantic–lexical system is sufficient to ensure the correct response.

In word transcoding tasks (that is, in tasks that require the conversion of an auditorially or visually presented word into a spoken or a written response) semantic–lexical mechanisms are supplemented by sublexical conversion procedures. In the normal subject, the latter are used in the spoken or written production of novel words, and have no overt consequences on the transcoding of familiar words. The hypothesis in figure 1 assumes that sublexical procedures are activated also when the stimulus to be read (or written, or repeated) is a word. In particular, it proposes (Hillis & Caramazza 1991*a*; see also Newcombe & Marshall (1980) and Saffran (1985) for slightly different views) that in transcoding tasks the above-threshold activation of entries in the output lexicons results from the summation of semantic and sublexical information. For example, in reading aloud, the selection of the correct entry in the phonological output lexicon is determined by the summation of semantic information and of information assembled by sublexical grapheme–phoneme conversion procedures. Thus, normal subjects are able to read aloud (and write to dictation, and repeat) words correctly by virtue of semantic–lexical information (which in itself would be sufficient for this purpose, see above) and of sublexical conver-

† The alternative hypothesis that there is a common phonological lexicon, used for input and output, and a common orthographic lexicon, also used for input and output, was proposed by Allport (1987) and, more recently, by Marslen-Wilson, Tyler, Waksler & Older (1994).

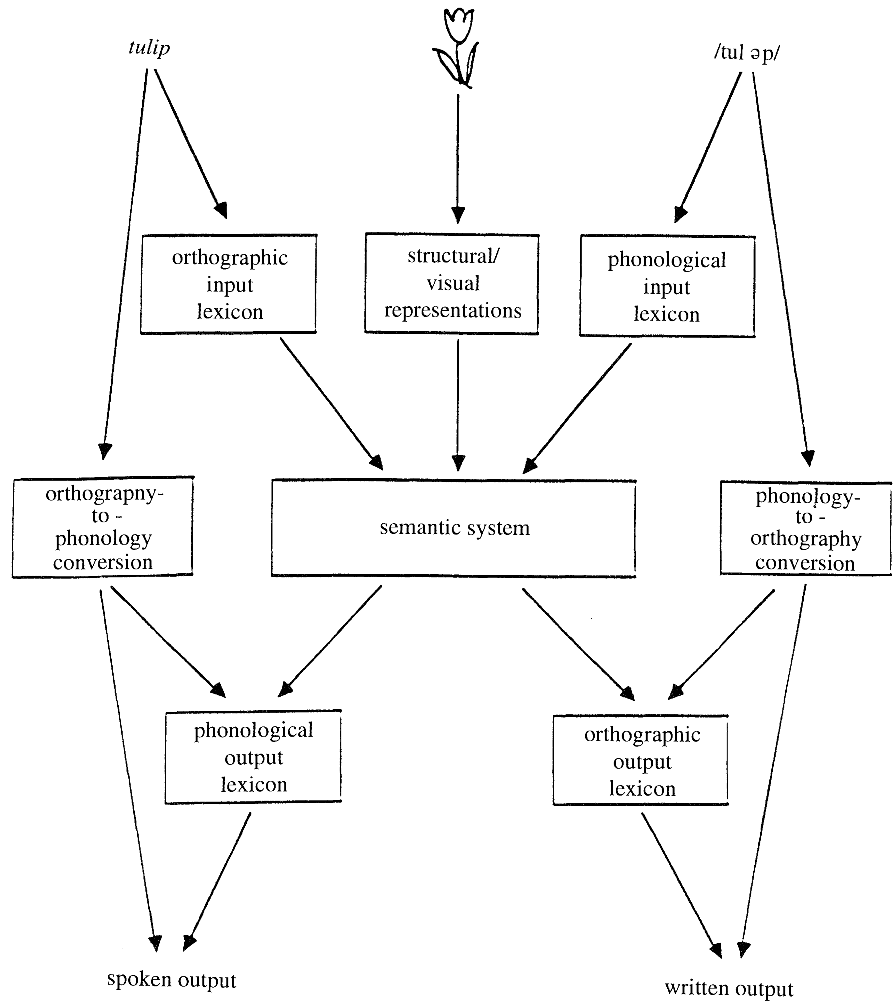

Figure 1. Schematic representation of the lexical–semantic system.

sion‡. The consequences of this hypothesis for word processing in brain-damaged patients will be discussed later.

In addition to providing the basic distinctions that underlie the functional architecture of the lexical–semantic system, analyses of cognitively impaired subjects have clarified aspects of the internal structure of its subcomponents. Numerous reports have shown that brain damage can selectively impair specific semantic categories, such as abstract/concrete nouns (see, for example, Warrington 1975, 1981); proper names (see, for example, Semenza & Zettin 1988), geographical names (see, for example, McKenna & Warrington 1978), body parts (see, for example, Dennis 1976), living/non-living things (see, for example, Warrington & Shallice 1984; Warrington & McCarthy 1987), animals (Hillis & Caramazza 1991*b*) and so on. The role of grammatical class in the organization of the semantic lexical system has also been demonstrated repeatedly (Caramazza & Hillis 1991; McCarthy & Warrington 1985; Miceli *et al.* 1984).

Analyses of aphasic performance have also played a significant role in demonstrating that the semantic–lexical system is organized along the morphological dimension. Selective impairment and selective sparing of morphology have been repeatedly described in disorders of sentence production. Morphologically impaired output in the presence of spared production of major-class lexical items has been frequently shown in so-called 'agrammatic' speakers (see, for example, Goodglass *et al.* 1972; Menn & Obler 1990). The opposite picture (spared morphology in the presence of damage to major-class lexical items) has been observed in so-called 'neologistic jargonaphasic' patients (see, for example, Butterworth & Howard 1987; Caplan *et al.* 1972). These contrasting patterns of performance have been used to argue that the cognitive subsystems responsible for the processing of grammatical morphemes in sentences are functionally independent from those involved in processing content words (see, for example, Garrett 1982). Recent reports have shown that the same distinction also applies at the single-word level. The neuropsychological evidence supporting morphological organization in the lexical–semantic system is the focus of this paper.

‡ Note that the interaction between lexical–semantic and sublexical procedures occurs only in transcoding tasks, and not in tasks like oral/written picture naming or spontaneous speech/writing. In the latter tasks, the relationship between input and output (for example, between an object and its name) is arbitrary, and sublexical procedures are not activated.

2. THE REPRESENTATION OF MORPHOLOGY IN THE LEXICAL–SEMANTIC SYSTEM: PATIENT FS.

Italian patient FS (Miceli & Caramazza 1988) is a right-handed lawyer, 62 years old, who suffered from an intracerebral hemorrhage involving the fronto-temporoparietal structures of the left hemisphere. In the context of 'agrammatic' speech, a severe repetition disorder was demonstrated. FS produced incorrect responses to 893/1748 (50.1%) polymorphemic words. Of these, 659 (74%) resulted in incorrect words, 186 (21%) in incorrect non-words, and 48 (5%) in unscorable responses. Almost all the words produced in error were morphologically incorrect (636/659, 97%), as in *correre*, to run → *correva*, was running. Several analyses supported the hypothesis that these errors resulted from damage to a component of the semantic–lexical system organized on the basis of morphological structure, and not from a phonological disorder. The clearest case was provided by the performance in repeating adjectives (table 1). In Italian, some adjectives are marked for gender and number (for example, 'good' corresponds to *buon**o***, m.sg., *buon**a***, f.sg., *buon**i***, m.p.l., *buon**e***, f.pl.), others for number only (for example, 'strong' corresponds to *fort**e***, sg., *fort**i***, pl.). With the first type of adjective, FS produced significantly more correct responses to the m.sg. (149/157, 94.9%) than to the other forms (overall correct performance on non-m.sg. adjectival forms: 85/219, 38.8%). In addition, incorrect production of the m.sg. accounted for 117/144 (81.2%) errors to non-m.sg. forms. The same response distribution was observed on all four-ending adjectives, independent of whether the m.sg. was the most or the least frequent form of the adjectival paradigm. In addition, FS produced more correct responses in repeating the final *-e* in the context of two-ending adjectives, where it corresponds to the sg. form (59/69, 81.2%), than in the context of four-ending adjectives, where it corresponds to the f.pl. form (14/55, 25.5%).

Table 1. *Confusion matrix for inflectional errors produced by FS in repeating four-ending and two-ending adjectives*

Rows: stimulus; columns: response. Percentages are reported in parentheses.

1. Four-ending adjectives

	m.sg.	m.pl.	f.sg.	f.pl.	total
m.sg.	**149 (94.9)**	8 (5.1)	—	—	157
m.pl.	40 (52.6)	**26 (34.2)**	5 (6.6)	5 (6.6)	76
f.sg.	43 (48.9)	1 (1.1)	**35 (39.8)**	9 (10.2)	88
f.pl.	34 (61.8)	2 (3.6)	5 (9.1)	**14 (25.5)**	55
total	266 (70.7)	37 (9.8)	45 (12.0)	28 (7.4)	376

2. Two-ending adjectives

	sg.	pl.	total
sg.	**56 (81.2)**	13 (18.8)	69
pl.	36 (65.5)	**19 (34.5)**	55
total	92	32	124

This pattern of performance rules out a phonological disorder, and is best accounted for by damage to a mechanism organized on morphological principles; in other words, by assuming that morphology is represented in the semantic–lexical system. FS's behaviour is consistent with two hypotheses. The first possibility is that morphological structure is represented both in the semantic and in the lexical component. On this view, repeating a polymorphemic word involves the activation of a morphologically complex semantic representation, which in turn activates root and affix morphemes, independently represented in the phonological output lexicon. In FS's case, an impairment of suffix representations in the output lexicon yielded many incorrect responses consisting of the correct root followed by an incorrect suffix.

There is an alternative possibility, however. A very large number of morphologically incorrect words in repeating polymorphemic stimuli requires the assumption that morphology is represented somewhere in the semantic–lexical system, but not that it is represented in both the semantic and the lexical component. The same performance could be accounted for also by assuming that morphological information is represented only in the semantic system, and that lexical representations consist of whole words, as opposed to morphemes. On this account, repetition of a polymorphemic word requires that a morphologically complex semantic representation activate the corresponding whole-word entry in the output lexicon. In FS's case, phonological output lexicon damage caused at times the correct semantic representation to activate an incorrect, morphologically related whole-word representation.

The latter interpretation is unlikely to be correct. In addition to morphologically incorrect words, FS also produced some non-word errors consisting of the appropriate root paired with a suffix not permissible for that root. For example, he repeated *morivi* (you were dying) as **moressi*, an illegal combination of the verb root *mor-* (third conjugation) with the suffix *-essi* (appropriate for second conjugation verbs). These errors favor the hypothesis that morphology is represented both in the semantic and in the lexical component, but they were too few for reliable analyses. A much larger corpus of morphological non-word errors was obtained from the next patient, who provided the evidence needed to decide between the two accounts of morphological representation in the lexicon.

3. MORPHOLOGICAL COMPOSITION IN THE PHONOLOGICAL OUTPUT LEXICON: PATIENT SJD.

Patient SJD (Badecker & Caramazza 1991) is a right-handed librarian, 48 years old, whose aphasia resulted from ischaemic damage to the left frontoparietal structures. In consideration of accurate performance on visual lexical decision and comprehension tasks, her reading deficit was attributed to an output disorder. SJD read aloud correctly 2409/3005 words

(80.2%). Most errors (388/596, 65.2%) were morphological (HELPFUL → *helpless*; TOUCHED → *touch*). She also produced errors resulting in phonemically related words, for example HAPPEN → *happy* (109/596, 18.3%), and in phonemically related non-words, for example VIVID → /sIvId/ (79/596, 13.3%).

The 133 morphological errors resulting from affix substitutions were studied in detail. Of these, 74 (55.6%) resulted in incorrect words (SPRAYS → *sprayed*), and 59 (44.4%) in morphologically complex non-words, consisting of the correct root paired to a non-permissible suffix (DISCUSSING → **discussionly*). Unsolicited comments demonstrated that SJD had recognized the stimulus and accessed the appropriate semantic information, even when she had produced an incorrect response (for example, PUBLISHER → 'publish, someone who makes a magazine, book, newspaper'; POOREST → '*poorless, the most poorless Indians have very little money').

To conclude that SJD's performance demonstrated morphological organization in the output lexicon, it had to be shown that errors scored as morphological actually resulted from damage to the morphological subcomponent of the phonological output lexicon, and not from a phonological impairment.

Morphologically incorrect word responses were considered first. To consider these errors as putatively phonological, it would have to be shown that they resulted from selecting a phonological neighbour of the target word in the output lexicon. Because the set of phonological neighbours also includes morphologically related words, a phonological deficit should yield both phonological and morphological errors, independent of whether or not the stimulus has morphological structure. On this account, apparently disparate errors such as INVENTIVE → *invention* and MOVEMENT → *moment* would arise from the same source: access to an incorrect entry in the phonological output lexicon. The phonological account predicts that, when reading homophones, SJD should attain identical performance on polymorphemic and monomorphemic stimuli. She should be equally accurate in pronouncing a polymorphemic world like ALLOWED and the homophonous, monomorphemic word ALOUD. In addition, if her seemingly morphological errors result from inappropriately selecting a word phonologically related to the target, SJD should incorrectly respond /əlau/ (*allow*) to both ALLOWED and ALOUD (/əlau/ is a phonological neighbour of /əlaud/, which is the pronunciation of ALLOWED and ALOUD). The patient's performance stands in stark contrast with this prediction (table 2). SJD read incorrectly 13/26 (50%) polymorphemic words (like ALLOWED), but only 4/26 (15.4%) monomorphemic words (like ALOUD). In addition, she produced morphological errors only to polymorphemic words (11/26, 42.3%). That is, she read ALLOWED → *allow*, but not ALOUD → *allow*, as she should have on the phonological account. Thus, the morphologically incorrect words produced by SJD result from morphological damage, and cannot be construed as phonologically based lexical mis-selections.

Table 2. *Performance obtained by SJD in reading affixed and non-affixed homophones*

Percentages are in parentheses.

	affixed (ALLOWED)	unaffixed (ALOUD)
incorrect responses	13/26 (50)	4/26 (15)
morphological errors	11/26 (42)	—
phonemic errors	2/26 (8)	4/26 (15)

Morphological non-word errors like DISCUSSED → **discussionly* and NEWER → **newing* could be considered as phonological if it could be demonstrated that they resulted from omission of the suffix, followed by its substitution with a phoneme sequence that by chance is homophonous to an incorrect suffix. This account predicts that, in addition to resulting in morphological non-words, several responses to polymorphemic words should consist of the correct root followed by a sequence that does not correspond to a suffix (WALKED → /'wɔ kif/). Contrary to this hypothesis, only 1/79 phonemic non-word errors could be reconstructed in this way (MOVEMENT → /'muvnεt/). This isolated error contrasts markedly with the 59/133 morphological non-word responses containing a root followed by a non-permissible suffix, and with the 74 morphologically related words. A further argument for the hypothesis that these errors are morphologically based is that the suffixes involved in substitutions are not the most frequent, but the most productive in the language. Thus, the suffix substitutions resulting in non-words produced by SJD are also true morphological errors.

As in FS, the production of morphologically incorrect words is inconclusive as to whether morphological structure is represented in the output lexicon. However, the 59 morphological substitutions that resulted in non-words provide the relevant evidence. These errors cannot be due to the activation of incorrect whole-word representations. They can only result from combining the correct root with an incorrect suffix, inappropriately selected in a distinct component of the lexicon, organized according to morphological structure.

This pattern of performance supports the view that lexical representations used for spoken output are morphemes, and not whole words. In speech production, root morphemes and roots in the output lexicon are activated by morphologically complex semantic representations, and are subsequently composed before verbal output.

4. MORPHOLOGICAL COMPOSITION IN THE ORTHOGRAPHIC OUTPUT LEXICON: PATIENT DH.

Results consistent with a similar organization in the orthographic output lexicon were observed in subject DH (Badecker *et al.* 1990). Spelling accuracy in this patient depended on stimulus length. He spelled correctly more polymorphemic words like *smokes* than monomorphemic words of comparable length and frequency, like *sudden*. In addition, errors produced to monomorphemic and polymorphemic words had a different distribution. Errors in spelling the former increased steadily from initial to final positions; errors in spelling the latter increased from initial to final positions within the root, and from initial to final positions within the affix. This pattern of performance is consistent with the view that polymorphemic words are represented in the orthographic output lexicon in morphologically decomposed form, and that their constituent morphemes are composed along the morphological dimension at later stages of the output process.

5. MORPHOLOGICAL DECOMPOSITION IN THE INPUT LEXICONS

A similar, temporally reversed sequence of events takes place in processing written words for input. Evidence consistent with morphological decomposition in input processes has been reported in Italian dyslexic patient LB (Caramazza *et al.* 1985). He read aloud correctly 380/388 words (98%), but only 238/388 non-words (61%). Accuracy in non-word reading was critically influenced by whether or not the stimulus could be parsed morphologically. LB was asked to read morphological non-words like CHIEDIVA, consisting of a verb root (CHIED-, second conjugation) paired with a non-permissible suffix (-IVA, appropriate for third conjugation verbs), and non-words matched for length, orthographic structure and visual similarity to words, but without morphological structure, like CHIADOVA. He read correctly 76/100 stimuli of the first type, and 51/100 stimuli of the second type. This observation is consistent with the view that written input strings are decomposed along the morphological dimension, resulting in the activation of root and affix morphemes in the orthographic input lexicon.

Data from auditory input processing are not as clear as those obtained for written input, perhaps due to the different nature of the input (all the letters of a written stimulus are simultaneously present in front of the subject, and can be processed in parallel, whereas processing the sounds of a phoneme string is more 'sequential'). However, evidence provided by studies of auditory sentence processing (see, for example, Tyler *et al.* 1990) is consistent with the view that also the mechanisms involved in auditory input processing are sensitive to morphological structure, and that roots and morphemes have independent representations in the semantic–lexical system.

The studies reviewed in §§ 2–5 suggest that lexical representations consist of morphemes, and that inflected words are fully decomposed into roots and suffixes in the lexicon. During input processes, written (and presumably also auditory) strings are decomposed into their morphological constituents, to access root morpheme and inflection representations in the input lexicons and, subsequently, morphologically complex semantic representations. The reverse happens in spoken and written production: morphologically based semantic information activates root morphemes and suffixes in the output lexicon. The morphological segments thus activated are subsequently composed for production.

6. INFLECTIONAL AND DERIVATIONAL MORPHOLOGY

Inflectional and derivational morphology have been distinguished on theoretical grounds (for reviews, see Bybee 1985; Scalise 1984). Neuropsychological studies provide support for the separate representation of inflectional and derivational morphology in the lexicon.

In repetition, patient FS (Miceli & Caramazza 1988) produced very many morphologically incorrect responses. Errors to words that contained a root and an inflection (*parla*, speaks), and to words that contained a root, one or more derivations and an inflection§ (*realizzazioni*, realizations) were analysed separately. FS produced 96% (492/511) inflectional errors and 1% (5/511) derivational errors to inflected-only words, and made 83% (90/109) inflectional errors and 11% (12/109) derivational errors to derived words. To both stimulus types he also produced some ambiguous errors that could be scored as either inflectional or derivational. Thus, FS made virtually only inflectional errors to inflected words, and produced some derivational errors only to derived words. This fact supports the view that inflectional and derivational morphology are represented separately. Results consistent with this hypothesis were obtained in an auditory word monitoring task by patient DE (Tyler & Cobb 1988), who was sensitive to the contextual appropriateness of derivational, but not of inflectional, suffixes in sentences.

The issue of how derived words are represented in the lexicon is less well established. The results reported in the previous paragraph prompted the conclusion that inflectional and derivational morphology have distinct representations in the lexicon. FS's performance led to propose that inflected words are fully decomposed in the lexicon into their constituent morphemes (the results obtained in the patients reviewed so far are entirely consistent with this view). The distribution of inflectional and derivational errors to derived words, by contrast, was deemed consistent with the hypothesis that words of this type are only partially decomposed, into base form + inflection. For example, the word *realizations* would be represented in the lexicon as *realization* + *s*, and not as *real* + *iz* + *ation* + *s*. This hypothesis is supported by data from visual lexical decision experiments in normals (see, for example, Laudanna *et al.* 1992).

§ In Italian, almost all derived words (adverbs are the obvious exception) are also inflected.

However, errors reported in other brain-damaged patients suggest more extensive morphological decomposition than has been hypothesized on the basis of FS's errors. For example, many affix substitutions observed in SJD (Badecker & Caramazza 1991) resulted in the incorrect production of the most productive derivations, independent of whether they resulted in words or in morphologically illegal non-words. Another case in point is patient RB (Semenza *et al.* 1990). In spontaneous speech, this patient produced derived words, few of which (65/828, 7.8%) contained productive derivations, and derived neologisms, many of which (41/86, 47.7%) resulted from combining a non-existing root with a very productive derivation.

The apparent contrast between the conclusions drawn on the basis of FS's performance and from the pattern of performance observed in SJD and RB can be accommodated by the model. The lexical representation of a derived word, which is normally used for production, is decomposed into base form + inflection (*realization* + *s*). However, the lexicon also contains separate representations of roots (*real-*) and suffixes, both derivational (*-iz-*, *-ation-*) and inflectional (plural *-s*). When a base form is unavailable, root and affix representations can still be used to support the production of derived words (with this respect, the hypothesis is similar to that proposed by Semenza *et al.* (1990)). The correct target may still be produced, especially in the case of semantically and phonologically transparent words. However, if the target is an opaquely derived word, or if there is additional damage to affixes or derivational rules, morphologically illegal forms may be produced, as reported in SJD and RB.

It is also possible that various derived words are decomposed to a different extent. This diversity could be justified by the fact that derivations differ (much more than inflections) in terms of productivity, and that derived words vary in semantic and phonological transparency with respect to their base forms. Perhaps derived words that contain very productive affixes and that are transparently related to their base-form both phonemically and semantically are represented in fully decomposed fashion, whereas opaquely derived words are represented only as base form + inflection (for a discussion on this issue, see Bybee (1985) and Marslen-Wilson *et al.* (1994). Clearly, more research is needed in order to clarify this issue.

7. THE CO-OCCURRENCE OF MORPHOLOGICAL, PHONEMIC OR GRAPHEMIC AND SEMANTIC ERRORS

It is a striking but very consistent observation that morphological errors do not occur in isolation. In the literature there is not a single report of a patient who produces only morphological errors. Morphologically incorrect responses have been found to co-occur with phonemic or orthographic errors, with semantic errors, and with both. Morphological errors have been observed to co-occur with phonological errors in spoken output (Badecker & Caramazza, 1987, 1991; Miceli & Caramazza, 1988) and with orthographic errors in spelling (Shallice 1981; Bub & Kertesz 1982). The co-occurrence of morphological errors with both semantic and phonemic or orthographic errors has been reported in patients with disorders of reading (see, for example, Badecker & Caramazza 1987; Coltheart *et al.* 1980; Funnell 1987), writing (see, for example, Nolan & Caramazza 1983; Patterson & Shewell 1987), and repetition (see, for example, Howard & Franklin 1988; Katz & Goodglass 1990; Miceli *et al.* 1994). In at least one case, morphological and semantic paralexias occurred in the absence of phonemic errors (Caramazza & Hillis 1990).

The empirical problems posed by these co-occurrences have been shortly exemplified earlier in this paper, when discussing the performance of patients FS and SJD. The pattern of errors observed in these two patients has been used to argue for representation of morphology in the lexical–semantic system. However, because both cases produced a fair number of unequivocal phonological errors, lengthy and complex analyses had to be performed to demonstrate that errors initially scored as morphological actually resulted from a morphological (as opposed to a phonological or a semantic) disorder. Eventually, the conclusion that the repetition errors produced by FS were truly morphological required the analysis of the incorrect responses observed in repeating adjectives; in SJD's morphological paralexias, the same conclusion was reached only after careful scrutiny of morphological and phonemic errors. Other studies had a less fortunate outcome: even careful analyses did not license clear-cut conclusions on the origin of putatively morphological errors (see, for example, Badecker & Caramazza 1987; Funnell 1987).

Thus, the simultaneous occurrence of morphological, phonological and semantic errors is a very common finding, that poses non-trivial problems of interpretation. A major problem that faces neuropsychological research on the morphological organization of the linguistic system is to make sense out of these co-occurrences.

(a) The Co-occurrence of morphological and semantic errors

The model of the semantic–lexical system represented in figure 1 may help interpret the co-occurrence of semantic and morphological errors in transcoding tasks (that is, in tasks like reading aloud, writing to dictation, repetition, etc., that require the conversion of an auditory or a visual input into a verbal or a written output). It assumes that, under normal conditions, the selection of the correct form in the output lexicon is determined by the summation of

* Damage to these mechanisms is typically demonstrated by the inability to transcode non-words.

information from the semantic component and from the sublexical conversion procedures involved in a particular task (Caramazza & Hillis 1991*a*). This hypothesis poses severe constraints on the form that cognitive damage must take in order to result in the selection of an incorrect lexical representation in transcoding tasks. Production of a semantic error (ORANGE → *pear*) presupposes combined damage to the semantic and/or the output lexical component of the semantic–lexical system, and to the sublexical conversion procedures involved in that task*. In fact, a review of the literature quoted in the first paragraph of § 7 shows that semantic paralexias were observed only in cases of co-occurring damage to the lexical–semantic system and to sublexical grapheme–phoneme conversion; semantic paragraphias only in case of co-occurring damage to the lexical–semantic system and to sublexical phoneme–grapheme conversion; and, semantic errors in repetition only in case of co-occurring damage to the lexical–semantic system and to sublexical phoneme(input)–phoneme(output) conversion.

In discussing the co-occurrence of morphological and semantic errors, the summation hypothesis must be articulated in the light of the results presented in §§ 2–5. These results demonstrate that morpho-semantic and morpholexical information is represented independently from semantic and lexical information on roots. In this framework, both semantic and morphological errors can be construed as mis-selections of a lexical representation: of an incorrect root in 'semantic' errors, and of an incorrect affix in 'morphological' errors. The production of one or the other type of error depends on the site of damage to the semantic–lexical system. If damage affects root representations, semantic errors (e.g., ORANGE → *pear*) will occur, whereas damage to representations of affixes will result in morphological errors (e.g., TALKING → *talked*). Thus, the summation hypothesis can account for all the possible combinations of semantic and morphological errors. In the presence of damage to sublexical conversion procedures: both error types should co-occur when semantic–lexical damage affects both root and affix representations; semantic errors alone should occur when root representations are selectively damaged; and morphological, but not semantic, errors should be observed in the case of selective damage to affix representations.

The pattern observed in FS and SJD conforms precisely to the last prediction. Patient FS, who produced morphological but not semantic errors in repetition, also suffered from severe damage to sublexical phoneme(input)–phoneme(output) conversion, as shown by extremely poor performance in non-word repetition (28/283 correct responses, 9.9%). Patient SJD, who produced morphological but not semantic paralexias, also demonstrated severe damage to sublexical grapheme–phoneme conversion. In fact, she read correctly 127/140 (90.7%) monomorphemic words but only 25/140 (17.8%) non-words matched for length and phonological structure.

(b) The co-occurrence of morphological and phonemic errors

The co-occurrence of morphological and phonological errors is at least as frequent as the co-occurrence of morphological and semantic errors, but is harder to explain. It may have substantially different meanings, depending on the hypotheses entertained on the nature of the mechanisms and representations involved in the activation and in the production of the phonological form of a polymorphemic word‖. At least two contrasting hypotheses can be considered¶.

It can be assumed that in the production of a polymorphemic word (e.g. *realizations*) all the lexical morphological processes take place before a phonological form is activated. On this view, phonemic errors in a patient who makes morphological errors could be merely a by-product of the complex cognitive damage that must occur in order for an impairment to the morphological component of the lexical–semantic system to result in morphological errors. That is, because morphological errors presuppose damage to several components of the cognitive system (see § 7*a*), the co-occurrence of phonemic errors could be an accidental (but perhaps inevitable) association, resulting from the extension of the cognitive damage to components other than the morphological. To mention just an example, a patient who makes morphological errors due to semantic–lexical and sublexical damage might produce a phonemic error if, after morphological composition, part of the target phonological representation is unavailable, and missing or underspecified phonemes are unsuccessfully 'repaired' in later stages of the output process. Be that as it may, under the assumption that all morphological processes take temporal precedence over phonological processes, phonemic errors are unlikely to reflect interesting properties of the morphological components of the lexical–semantic system. They could be safely ignored in the analyses of patients who make morphological errors, if it could be demonstrated that putative morphological errors are indeed caused by damage to morphologically based mechanisms.

Alternatively, morphological and phonological processes could be tightly interwoven. For example, the theory of lexical phonology (Kiparsky 1982) proposes that, in polymorphemic words, suffixes are attached to roots in successive cycles. At the end of each morphological cycle, a phonological representation is realized, which serves as input to the next morphological cycle. The phonological representation obtained after the last morphological cycle is subsequently produced. Because on this account phonology and morphology are inextricably linked, the co-occurrence of morphological and phonological errors

‖ An identical reasoning could be developed for the production of orthographic forms.

¶ Note that the arguments that follow are largely independent of the assumptions on the nature (e.g., linear vs. non-linear) of phonological representations.

could be functionally necessary (except, perhaps, when damage to morphology affects only the last morphological cycle, but not the final phonological representation). In addition, within this theoretical framework the analysis of phonological errors might reveal theoretically relevant properties of the morphological organization of the lexical–semantic system.

Unfortunately, however important the distinction between the two classes of hypotheses and its consequences on neuropsychological studies of morphological organization, the limitations of current theories do not allow a motivated choice. It is to be hoped that further research in this area will help clarify the complex relationships existing between morphological and phonological processes.

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REFERENCES

Allport, A. & Funnell, E. 1981 Components of the mental lexicon. *Phil. Trans. R. Soc. Lond.* B**295**, 397–410.

Badecker, W. & Caramazza, A. 1987 The analysis of morphological errors in a case of acquired dyslexia. *Brain Lang.* **32**, 278–305.

Badecker, W. & Caramazza, A. 1991 Morphological composition in the lexical output system. *Cogn. Neuropsychol.* **8**, 335–368.

Badecker, W., Hillis, A. & Caramazza, A. 1990 Lexical morphology and its role in the writing process: Evidence from a case of acquired dysgraphia. *Cognition* **35**, 205–243.

Bub, D. & Kertesz, A. 1982 Evidence for lexicographic processing in a patient with preserved written over oral single word naming. *Brain* **105**, 697–717.

Butterworth, B. & Howard, D. 1987 Paragrammatisms. *Cognition* **26**, 1–37.

Bybee, J.L. 1985 *Morphology*. Amsterdam: John Benjamins Publishing Company.

Caplan, D., Kellar, L. & Locke, S. 1972 Inflection of neologisms in aphasia. *Brain* **95**, 160–172.

Caramazza, A. & Hillis, A 1990 Where do semantic errors come from? *Cortex* **26**, 95–122.

Caramazza, A. & Hillis, A. 1991 Lexical organization of nouns and verbs in the brain. *Nature, Lond.* **349**, 788–790.

Caramazza, A., Miceli, G., Silveri, M.C. & Laudanna, A. 1985 Reading mechanisms and the organization of the lexicon: Evidence from acquired dyslexia. *Cogn. Neuropsychol.* **2**, 81–114.

Coltheart, M., Patterson, K.E. & Marshall, J.C. (eds) 1980 *Deep dyslexia*. London: Routledge & Kegan Paul.

De Bleser, R. & Bayer, J. 1988 Morphological reading errors in a German case of deep dyslexia. In *Morphology, phonology, and aphasia* (ed. J.-L. Nespoulous & P. Villiard), pp. 32–59. New York: Springer-Verlag.

Dennis, M. 1976. Dissociating naming and locating of body parts after left anterior temporal lobe resection: An experimental case study. *Brain Lang.* **3**, 147–163.

Funnell, E. 1987 Morphological errors in acquired dyslexia: A case of mistaken identity. *Q. Jl exp. Psychol.* **39**A, 497–539.

Garrett, M. 1982 Production of speech: Observations from normal and pathological language use. In *Normality and pathology in cognitive functions* (ed. A. W. Ellis), pp. 19–76. London: Academic Press.

Goodglass, H., Gleason, J.B., Bernholtz, N.A. & Hyde, M.R. 1972 Some linguistic structures in the speech of a Broca's aphasic. *Cortex* **8**, 191–211.

Hillis, A. & Caramazza, A. 1991*a* Mechanisms for accessing lexical representations for output: Evidence from a category-specific semantic deficit. *Brain Lang.* **40**, 106–144.

Hillis, A. & Caramazza, A. 1991*b* Category specific naming and comprehension deficit: A double dissociation. *Brain* **114**, 2081–2094.

Howard, D. & Franklin, S. 1988 *Missing the meaning?* Cambridge, Massachusetts: MIT Press.

Katz, R.B. & Goodglass, H. 1990 Deep dysphasia: Analysis of a rare form of repetition disorder. *Brain Lang.* **39**, 153–185.

Kiparski, P. 1982 Lexical morphology and phonology. In *Linguistics in the morning calm* (ed. I.-S. Yang), pp. 3–91. Seoul, Korea: Hanshin.

Laudanna, A., Badecker, W. & Caramazza, A. 1992 Processing inflectional and derivational morphology. *J. Mem. Lang.* **31**, 333–348.

Marslen-Wilson, W., Tyler, L.K., Waksler, R. & Older, L. 1994 Morphology and meaning in the English mental lexicon. *Psychol. Rev.* **101**, 3–33.

McCarthy, R. & Warrington, E.K. 1985 Category-specificity in an agrammatic patients: The relative impairment of verb retrieval and comprehension. *Neuropsychologia* **23**, 709–727.

McKenna, P. & Warrington, E.K. 1978 Category-specific naming preservation: A single case study. *J. Neurol. Neurosurg. Psychiatr.* **41**, 571–574.

Menn, L. & Obler, L.K. (eds) 1990 *Agrammatic aphasia*. Philadelphia: John Benjamins.

Miceli, G., Capasso, R. & Caramazza, A. 1994 The interaction between lexical and non-lexical mechanisms in reading, writing, and repetition. *Neuropsychologia* **32**, 317–333.

Miceli, G. & Caramazza, A. 1988 Dissociation of inflectional and derivational morphology. *Brain Lang.* **35**, 24–65.

Miceli, G., Silveri, M.C., Villa, G. & Caramazza, A. 1984 On the agrammatics' difficulty in producing main verbs. *Cortex* **20**, 207–220.

Newcombe, F. & Marshall, J.C. 1980 Transcoding and lexical stabilization in deep dyslexia. In *Deep dyslexia* (ed. M. Coltheart, K. E. Patterson & J. C. Marshall), pp. 176–188. London: Routlege & Kegan Paul.

Nolan, K. & Caramazza, A. 1983 An analysis of writing in a case of deep dyslexia. *Brain Lang.* **20**, 305–328.

Patterson, K.E. & Shewell, C. 1987 Speak and spell: Dissociations and word-class effects. In *Cognitive neuropsychology of language* (ed. M. Coltheart, R. Job & G. Sartori), pp. 273–294. London: Lawrence Erlbaum Associates.

Saffran, E.M. 1985 Lexicalisation and reading performance in surface dyslexia. In *Surface dyslexia* (ed. K. E. Patterson, M. Coltheart & J. C. Marshall), pp. 53–72. London: Lawrence Erlbaum Associates.

Scalise, S. 1984 *Generative morphology*. Dordrecht: Foris Publishers.

Semenza, C., Butterworth, B., Panzeri, M. & Ferreri, T. 1990 Word formation: New evidence from aphasia. *Neuropsychologia* **28**, 499–502.

Semenza, C. & Zettin, M. 1988 Generating proper names: A case of selective inability. *Cogn. Neuropsychol.* **5**, 711–721.

Shallice, T. 1981 Phonological agraphia and the lexical route in writing. *Brain* **104**, 413–429.

Shallice, T. 1993 Multiple semantics: Whose confusions? *Cogn. Neuropsychol.* **10**, 251–262.

Tyler, L.K., Behrens, S., Cobb, H. & Marslen-Wilson, W. 1990 Processing distinctions between stems and affixes: Evidence from a non-fluent aphasic patient. *Cognition* **36**, 129–153.
Tyler, L. & Cobb, H. 1988 Processing bound grammatical morphemes in context: The case of an aphasic patient. *Lang. cogn. Procs* **2**, 245–262.
Warrington, E.K. 1975 The selective impairment of semantic memory. *Q. Jl exp. Psychol.* **27**, 635–657.
Warrington, E.K. 1981 Concrete word dyslexia. *Br. J. Psychol.* **72**, 175–196.
Warrington, E.K. & McCarthy, R. 1987 Categories of knowledge: Further fractionations and an attempted integration. *Brain* **110**, 1273–1296.
Warrington, E.K. & Shallice, T. 1984 Category specific semantic impairments. *Brain* **107**, 829–854.

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