

# The relationships between morphological and phonological errors in aphasic speech: data from a word repetition task

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## Abstract

Current theories of single-word processing predict that in some cases brain damage should selectively impair morphological processes, resulting in the selective occurrence of morphological errors. However, such a selective pattern of errors has never been documented, and the available case studies report the systematic association of morphological and phonological (segmental) errors in the same subject. The number of relevant case reports is very small, however. To better understand the relationship between morphological and phonological processes, we analyzed the repetition performance of 26 subjects who produced morphological errors in a screening battery for aphasia. Although the results confirm that subjects who make morphological errors also invariably make phonological errors, the probabilities of the two types of errors are not (quantitatively) correlated. Furthermore, the relationship between morphological and phonological errors was asymmetrical: although all subjects who produced morphological errors also produced phonological errors, some aphasics who produced phonological errors did not also produce morphological errors. The one-way relationship between morphological and phonological errors could result either from the anatomical proximity of the structures involved in morphological and phonological processes, or from the functional inseparability of the two processes. The fact that phonological errors can occur either in isolation or in association with morphological errors could be attributed to the functional heterogeneity of phonological errors, and to the separability of the neural substrates involved in processing various aspects of phonological information.

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## 1. Introduction

Neuropsychological investigations have repeatedly demonstrated that the semantic, lexical and segmental information about a word can be selectively impaired following left hemisphere lesions. Damage restricted to meaning representations has been repeatedly documented in subjects with cerebrovascular, infectious or degenerative disease of the left hemisphere (e.g., Hillis, Rapp, Romani, & Caramazza, 1990; Patterson & Hodges, 1992; Warrington, 1975). Similarly, a selective difficulty in producing segmental information in the presence of spared meaning and lexical information has been observed in subjects presenting with the so-called “conduction” aphasia (Hillis, Boatman, Hart, & Gordon, 1999). There are also numerous reports of selective damage in accessing lexical representations. Aphasic subjects with “pure anomia” have been reported

who cannot access the sound representation of a word, while retaining information about its meaning (Gainotti, Silveri, Villa, & Miceli, 1986; Kay & Ellis, 1987; Lambon Ralph, Sage, & Roberts, 2000). In some reports, the distinction between lexical and segmental information has been demonstrated in extremely pure forms. There are subjects with selective damage to conceptual (Cuetos, Aguado, & Caramazza, 2000) or to lexical information (Caramazza & Hillis, 1990), whose incorrect responses always result in semantically related words, as well as subjects with selective damage to segmental information, whose incorrect responses systematically result in nonwords (Caplan, Vanier, & Bakes, 1986; Caramazza, Papagno, & Rumel, 2000; Wilshire & McCarthy, 1996).

Lexical representations, however, specify more than the phonological and orthographic forms of words: they also include information about their grammatical properties and their possible morphological transformations. There are many reports indicating that brain damage can differentially affect access to nouns or verbs (e.g., Bak, O’Donovan,

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Xuereb, Boniface, & Hodges, 2001; Caramazza & Hillis, 1991; Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Miceli, Silveri, Villa, & Caramazza, 1984; Tranel, Adolphs, Damasio, & Damasio, 2001; Zingeser & Berndt, 1988). The interpretation of these dissociations is still a matter of debate. It has been argued that they reflect the impairment of semantic properties that distinguish between nouns and verbs, rather than the loss of grammatical category distinctions (e.g., Bird, Howard, & Franklin, 2000; Breedin, Saffran, & Schwartz, 1998; Marshall, Chiat, Ronson, & Pring, 1996; McCarthy & Warrington, 1985; Tranel et al., 2001). However, while the observed dissociations may not always result from a genuine deficit in processing words of a given grammatical class, in at least some cases there is sufficient evidence to show that this is probably the case (e.g., Berndt, Haendiges, Burton, & Mitchum, 2002; Caramazza & Shapiro, in press).

There are also many reports of morphological processing impairments. Disorders of morphological processing are systematically observed in so-called agrammatic aphasia (e.g., Goodglass, 1976). Difficulties with nominal, adjectival and verbal inflections are a common feature of agrammatic speech across different languages (e.g., Menn & Obler, 1990). The reverse picture, apparent sparing of morphological endings associated with the production of neologistic root morphemes, has been reported in jargonaphasia (e.g., Buckingham & Kertesz, 1976; Caplan, Kellar, & Locke, 1972; Semenza, Butterworth, Panzeri, & Ferreri, 1990). Morphological errors have also been documented at the single-word level, especially in the context of reading (e.g., Badecker & Caramazza, 1991; Coltheart, Patterson, & Marshall, 1980; Jarema & Kehayia, 1992; Kehoe & Whitaker, 1971; Laine, Niemi, Koivuselkä-Sallinen, & Hyönä, 1995; Luzzatti, Mondini, & Semenza, 2001; Marshall & Newcombe, 1973), but also in repetition (Kohn & Melvold, 2000; Miceli & Caramazza, 1988) and writing tasks (Badecker, Hillis, & Caramazza, 1990). The errors made by these subjects suggest that morphological processes may be represented independently of other word production mechanisms.

The putative demonstration that brain damage can independently affect lexical–morphological and segmental information is not air-tight. In fact, we are not aware of any case where difficulty in processing morphological information occurs completely independently of phonological processing difficulties. Subjects who make morphological errors in single-word processing tasks, systematically also make segmental errors in the same tasks. In some reported cases, the distribution and the nature of the errors observed were so complex that incorrect responses could not be confidently ascribed to a morphological disorder as opposed to an impairment of other input or output processing components (Badecker & Caramazza, 1987; Funnell, 1987). And in those subjects where a strong case could be made for a morphological processing deficit, morphological errors co-occurred with errors of other types (e.g., semantic or spelling errors),

which presumably originate at other stages of processing. For example, in repetition tasks, subjects FS (Miceli & Caramazza, 1988) and BD and JW (Kohn & Melvold, 2000) produced not only morphological errors but also phonemic errors (see also, for example, cases HH (Laine et al., 1995), DH (Badecker et al., 1990), MB (Luzzatti et al., 2001) who produced morphological and other types of segmental errors).

The evidence from analyses of aphasics' spontaneous speech (as opposed to errors at the single-word level) is also inconclusive. In agrammatic speech, varying numbers of segmental errors are also typically reported (e.g., Menn & Obler, 1990). Furthermore, since the published narratives are usually edited for phonemic errors in order to facilitate focusing on morphological and syntactic impairments, failure to explicitly report segmental errors in reports of agrammatic speech cannot be taken, in the absence of explicit experimental analyses to this effect, to demonstrate lack of such errors in the subject's speech. In neologistic jargonaphasia, apparent sparing of morphological endings in the face of difficulty retrieving word roots has been demonstrated for both inflectional morphology (e.g., "Yes, because I'm just *persessing* to one" (Caplan et al., 1972); "One of the nicest *fendllows*" (Buckingham & Kertesz, 1976)) and derivational morphology (e.g., "Tutto il *ternessico* che mi aspetta"—All the *xxxxx*ic awaiting for me (Semenza et al., 1990)). At face value, these errors are consistent with the independence of lexical–morphological information. Unfortunately, their occurrence is extremely low, and they are typically interspersed with instances of inappropriate use of inflectional endings (e.g., "This is the *oned* that I have" (Caplan et al., 1972)) or with long stretches of uninterpretable speech (Semenza et al., 1990). Considering the rarity of these errors (for which baseline statistics have not been provided), the neologistic context in which they occur, and the fact that morphological endings are of high-frequency, and hence are more likely to be produced in the presence of lexical damage, this pattern of performance, albeit suggestive, hardly constitutes evidence for the independence of lexical–morphological and phonological information.

Despite all these observations, basic questions remain unanswered. How strong is the relationship between the occurrence of morphological and segmental errors? And what are the implications of this relationship for theories of lexical access and the representation of morphological and phonological processes in the brain? Unfortunately, the number of case studies that could help interpret the puzzling observation of a strong association between morphological and segmental errors is limited. In fact, there are far fewer reports of morphological impairment than of damage to semantic or segmental information, or to other lexical dimensions. In this study, we analyzed the single-word repetition performance of a large number of aphasic subjects, selected because they produced morphological errors during a screening procedure for aphasia. Our goal was to ascertain whether or not the occurrence of phonological errors in aphasics who make

morphological errors is systematic, and to provide a neuroanatomically and functionally plausible account for the observed patterns of performance.

## 2. Methods

### 2.1. Subjects

This study has been approved by the ethics committee of the Università Cattolica, and has been performed in accordance with the ethical standards established by the 1964 Declaration of Helsinki. All participants gave their informed consent prior to their inclusion in the study.

Approximately 150 consecutive aphasic subjects were screened for the presence of morphological disorders, by means of the Batteria per l'Analisi dei Deficit Afasici (Miceli, Laudanna, Burani, & Capasso, 1994b), as part of their routine clinical evaluation. Aphasics with at least 8 years of formal education were considered for inclusion in the experimental sample, as well as some subjects with fifth-to-eighth grade education, whose premorbid linguistic skills were clearly superior to their level of formal education (this is the case for ECO and ASF, who were included in the sample). Only subjects who scored within normal limits on the non-verbal tasks of a standardized battery for

the assessment of diffuse mental deterioration (Carlesimo, Caltagirone, & Gainotti, 1996) were included in the study. Participants were tested at least 6 months post-onset, with the exception of FAL, who was seen 4 months post-onset. Testing always took place on an outpatient basis. Subjects who in repetition, reading, and oral naming tasks produced errors classifiable as morphological, and whose speech was either free from dysarthria, or sufficiently clear from the articulatory viewpoint as to allow unequivocal error scoring were retained beyond the screening stage. The essential biographic and lesion information for the 26 subjects who met all these criteria is reported in Table 1. It is worth stressing that, without exceptions, these subjects produced morphological errors also in spontaneous speech (although this latter aphasic behavior was not a selection criterion).

### 2.2. Materials

The subjects included in this project were asked to repeat the stimuli included in the Lexical Morphology Battery (Capasso, Miceli and Caramazza, unpublished). The battery is comprised of several sublists, controlled for variables related to morphological structure, and to other psycholinguistic parameters, such as frequency, length and grammatical class (see Appendix A). Overall, it includes 2270 words and 200 pseudowords.

Table 1  
Epidemiological information on the patients included in the study

Patient	Age	Years of education	Time post-onset	Etiology	Lesion site	LIPC involvement
FAL	43	13	2 years	ICVA	Not known	Not known
LAN	59	17	3 years	HCVA	Deep F	+
ABA	41	13	4 years	HCVA	FTP sup and deep	+
DBO	43	17	5 years	ICVA	FT	+
FCA	43	12	2 years	ICVA	Not known	Not known
ICA	74	13	5 years	PPA	F atrophy	+
ECA	65	16	3 years	ECVA	PTO	–
MCE	23	12	3 years	RA	Not known	Not known
ECO	60	5	2 years	ICVA	Deep F	–
FDP	50	8	5 years	RA	Deep TP	–
PGA	63	19	7 months	ICVAs	Not known	Not known
ALO	45	5	1 year	ECVA	Deep FT	+
MLO	36	13	1 year	Cardiac arrest	Not known	Not known
GMA	53	8	3 years	ICVA	FT	+
LMA	47	17	4 years	ICVA	Deep F	+
GME	69	19	4 months	ICVA	Not known	Not known
AMO	58	8	4 years	ICVA	PT sup and deep	–
RPA	29	18	1 year	ECVA	Deep F	+
EPA	48	17	4 years	ICVA	F sup and deep	+
VPI	45	12	3 years	AVM	Deep F	+
RRO	20	13	2 years	Open HT	Not known	Not known
ASF	39	5	1 year	ICVAs	P and T	–
ASM	44	8	2 years	ICVA	Deep FT	+
CSG	69	13	8 years	ICVA	Right FT	+(right)
FS	66	17	6 years	HCVA	Deep FTP	+
ATR	49	17	1 year	RA	PT	–

LIPC: left inferior precentral cortex; ICVA: ischemic cerebrovascular accident; ECVA: embolic cerebrovascular accident; HCVA: hemorrhagic cerebrovascular accident; RA: ruptured aneurysm; HT: head trauma; PPA: primary progressive aphasia; AVM: artero-venous malformation; F: frontal; T: temporal; P: parietal; O: occipital.

Stimuli were presented in three blocks, each including several sublists and administered over several sessions. Within each block, words from the various sublists were randomized. The first and the third block included only words ( $n = 760$  and  $960$ , respectively), the second block consisted of  $560$  words and  $200$  pseudowords. Before administering each block, and at the beginning of each session during which stimuli from that block were presented, subjects were told that they were going to be asked to repeat only words, or both words and pseudowords. Their task was to repeat the stimulus pronounced by the examiner. Upon request, a stimulus could be presented twice. Whenever subjects made more than one attempt at responding, the last response was retained for scoring.

Five subjects (ABA; FCA; ECO; MLO; CSG) completed only the first block of the Lexical Morphology Battery; four subjects (ALO; LMA; ASF; ASM) completed the battery (or portions thereof) more than once.

### 2.3. Error analysis

Errors were classified into the following categories.

#### 2.3.1. Morphological

**2.3.1.1. Inflectional.** The root/stem of the stimulus was produced correctly, but the inflection was produced incorrectly (in Italian, omitting the inflection would result in a nonword; no such errors were observed in our corpus). Examples: *alberi*, trees → *albero*, tree; *buona*, good, f.sg. → *buono*, good, m.sg.; *parliamo*, we talk → *parlare*, to talk.

**2.3.1.2. Derivational.** The root/stem of the stimulus was produced correctly, but the prefix or the derivational suffix was substituted or omitted. Examples: *prescrivere*, to prescribe → *descrivere*, to describe (prefix substitution); *prescrivere*, to prescribe → *scrivere*, to write (prefix omission); *utilizzare*, to use → *utilità*, usefulness (suffix substitution); *fioraio*, florist → *fiore*, flower (suffix deletion).

#### 2.3.2. Phonological

**2.3.2.1. Phonologically related words.** Incorrect words that shared at least 50% of the phonemes of the target. Examples: *parliamo*, we talk → *partiamo*, we leave; *matita*, pencil → *mattina*, morning; *sparare*, to shoot → *aprire*, to open.

**2.3.2.2. Phonologically related nonwords.** Incorrect sequences that are phonemically similar to the target (see phonologically related words) but do not correspond to a real word. Examples: *tavolo*, table → *\*tarolo*; *bambini*, boys → *\*randini*; *telefonato*, called, past part. → *\*merofenato*; *parlavano*, they were talking → *\*parlavero*.

#### 2.3.3. Mixed

Responses containing a phonological error in the root, and a morphological error in the prefix or in the suffix. Examples: *percorrere*, to go along → *\*rincottare*; *vantava*, he was boasting → *cantare*, to sing; *correvano*, they were running → *\*corbare*; *pollaio*, hen-house → *\*pellario*.

#### 2.3.4. Other

Responses that could not be unambiguously classified as being either morphologically or phonologically based. *Morphologically illegal responses*, consisting of the correct root and a suffix in an illegal combination, were scored in this group (e.g., *tornava*, he was coming back → *\*torneva*, in which *-eva* is appropriate for second conjugation verbs, but not first conjugation verbs like *tornare*; *necessità*, necessity → *\*necessività*). These errors were extremely rare. Also *responses with phonemic errors on a substituted suffix/prefix*, were scored as other errors (*cantavo*, /kan'tavo/, I was singing → *\*cantavoro*, /kan'tavoro/, possibly resulting from the substitution of the first sg. inflection /-avo/ with the third plural inflection /-avano/, and from the following phonemic distortion (/avano/ → \*/-avoro/). The other error category also included *semantic errors* (*veloce*, fast → *macchina*, car), *circumlocutions* (*coltello*, knife → *serve per tagliare*, you cut with it), *unrelated words* (*scendeva*, he was coming down → *piccolo*, small), *unrelated nonwords* (i.e., nonwords containing fewer than 50% of the phonemes of the stimulus, as in *dolorosi*, painful, m.pl. → /mal'tedyo/), *fragments* and *omissions*.

## 3. Results

### 3.1. Overall performance

We first consider the incidence of incorrect responses to familiar and novel words included in the Lexical Morphology Battery or in the other tasks aimed at assessing repetition performance. The number of incorrect responses produced by each subject to word and (when administered) nonword stimuli is reported in Table 2. Subjects ABA, FCA, ECO, MLO and CSG did not complete the nonword repetition sublist, and were excluded from this analysis.

The values reported in Table 2 show a very wide range of performance: in word repetition, incorrect responses ranged between 22/2270, or 2.4% (case GME) and 1705/2270, or 75.1% (case AMO); in nonword repetition, they ranged between 25/200, or 12.5% (case EPA) and 190/200, or 95% (case AMO). All subjects repeated words more accurately than nonwords, but the lexical status of a stimulus affected performance to different extents in different subjects. Thus, LMA, GME, RPA repeated words four to five times more accurately than nonwords, whereas DBO, PGA, ASM and ATR presented with roughly comparable performance on the two types of stimuli. However, none of our subjects made errors only on pseudowords, and performance accuracy on

Table 2  
Overall performance in word and nonword repetition tasks

Subject	Incorrect/ total words	Incorrect (%)	Incorrect/total nonwords	Incorrect (%)
FAL	397/2270	17.5	105/200	52.5
LAN	261/2270	11.5	162/200	19.0
ABA	33/760	4.3	N/A	
DBO	941/4540	20.7	102/400	25.5
FCA	40/760	5.3	N/A	
ICA	1148/2270	50.6	186/200	93.0
ECA	1373/2270	60.5	197/200	98.5
MCE	69/760	9.1	N/A	
ECO	126/1320	9.5	69/200	34.5
FDP	262/2270	11.5	70/200	35.0
PGA	415/2270	18.4	76/200	38.0
ALO	616/4540	13.6	136/400	34.0
MLO	70/760	9.2	N/A	
GMA	395/2270	17.4	59/200	29.5
LMA	73/2270	3.2	30/200	15.0
GME	55/2270	2.4	38/200	19.0
AMO	1705/2270	75.1	190/200	95.0
RPA	109/2270	4.8	58/200	29.0
EPA	140/2270	6.2	25/200	12.5
SPI	177/2270	7.8	63/200	31.5
RRO	1454/2042	71.2	178/200	89.0
ASF	3782/9080	41.7	618/800	77.2
ASM	1328/4540	29.2	184/400	46.0
CSG	176/760	23.2	N/A	
FS	1176/2270	51.8	186/200	93.0
ATR	410/2270	18.1	70/200	35.0

N/A: not administered.

the two types of stimuli was highly correlated (Pearson's  $r$  coefficient = 0.943;  $P < 0.001$ ).

### 3.2. Occurrence and distribution of morphological errors

The occurrence of inflectional and derivational errors, and of responses that were both inflectionally and derivationally incorrect is reported in Table 3. Errors of the latter type (e.g., *inutili*, useless, pl. → *utile*, useful, sg.) were very infrequent, and will not be considered further. The distribution of inflectional and of derivational errors shows a large variability across subjects. Morphologically based errors accounted for only 5/760 (0.6%) responses in CSG, but for as many as 558/2270 (24.6%) responses in FS. Inflectionally incorrect responses ranged between 3/760 (0.4%) in CSG and 475/2270 (20.9%) in FS, and derivational errors ranged between 2/760 (0.3%) in CSG and 81/2270 (3.6%) in FS. In all cases, derivational errors were less frequent than inflectional errors, but the two error types were significantly correlated (Pearson's  $r = 0.912$ ;  $P < 0.001$ ). There are at least two reasons for why inflectional errors occur more frequently than derivational errors. First, on average, Italian words have more inflectionally related than derivationally related neighbors (for example, each verb form has over 40 inflectional neighbors, but far fewer derivational neighbors). This feature of the language results in more opportunities for inflectional than for derivational errors in the event of a

morphological deficit. Second, inflectionally related responses tend to be segmentally closer to the target than derivationally related responses. Consequently, the loss of segmental information is more likely to result by chance in an inflectional than in a derivational error.

### 3.3. Occurrence and distribution of non-morphological errors

The incidence of phonological, mixed and other errors is reported in Table 4. In this and the following table, word and nonword responses are collapsed under each heading.

Phonological errors accounted for only 20/2270 (0.9%) responses in EPA, and 36/2270 (1.6%) in GME, but for as many as 1092/2270 (53.5%) responses in RRO, and 554/2270 (24.4%) in AMO. Unsurprisingly, the subjects who made the largest numbers of morphological and phonological errors also produced more errors of the "mixed" type. However, these errors were too infrequent to allow reliable analyses. "Other" responses were also rare and will not be discussed in detail, except to note that, whenever they accounted for more than 1% of a subject's errors, they consisted mostly of fragments or of failures to respond. The only exception is ECA, who produced many semantic and circumlocutory errors (see also Miceli, Capasso, & Caramazza, 1994a).

### 3.4. The relative occurrence of morphological and phonological errors

It is obvious from Tables 3 and 4 that subjects who produce morphological errors also make errors of other types. Since this project focuses on the relationships between morphological and phonological processes, the analyses that follow are restricted to these two error types.

As a first step, for each subject the cumulative occurrence of inflectional and derivational errors was compared to the cumulative occurrence of phonological errors (that is, collapsing across incorrect responses resulting in words and pseudowords). The relative distribution of the two types of errors in each subject varies across a wide range (Table 5), and is not significantly correlated (Pearson's  $r = 0.143$ ;  $P = \text{NS}$ ).

Inspection of individual results reveals an interesting asymmetry. Most subjects produce comparable numbers of morphological and phonological errors (e.g., ASF: 16 and 14%; ASM: 10.7 and 13.9%; ECA: 11.1 and 13.2%), or present with a relative prevalence of morphological errors (e.g., FS: 24.6 and 15.5%) or of phonological errors (ICA: 5.3 and 19.9%). There is also a small number of subjects who make no morphological errors and many phonological errors, such as CSG (5/760, or 0.6% and 163/760, or 21.4%) and MLO (0/760 and 68/760, or 8.9%), or few morphological and very many phonological errors, such as RRO (68/2042, or 3.3% and 1092/2042, or 53.5%). However, there are no subjects with the reverse pattern, that is, who

Table 3  
Incidence of inflectional, derivational and inflectional-and-derivational errors out of total responses

Subject	<i>N</i>	Inflectional	Percentage	Derivational	Percentage	Inflectional-and-derivational	Percentage
FAL	2270	167	7.3	18	0.8	0	0.0
LAN	2270	30	1.3	3	0.1	0	0.0
ABA	760	9	1.2	3	0.4	0	0.0
DBO	4540	193	4.2	29	0.6	1	0.02
FCA	760	18	2.4	3	0.4	0	0.0
ICA	2270	96	4.2	20	0.9	4	0.2
ECA	2270	193	8.5	59	2.6	1	0.04
MCE	760	8	1.0	4	0.5	0	0.0
ECO	1320	21	1.6	7	0.5	0	0.0
FDP	2270	98	4.3	22	1.0	0	0.0
PGA	2270	122	5.4	19	0.8	1	0.04
ALO	4540	276	6.1	39	0.8	2	0.04
MLO	760	0	0.0	0	0.0	0	0.0
GMA	2270	145	6.4	16	0.7	1	0.04
LMA	2270	18	0.8	6	0.3	0	0.0
GME	2270	15	0.7	2	0.1	0	0.0
AMO	2270	118	5.2	25	1.1	1	0.04
RPA	2270	56	2.5	6	0.3	0	0.0
EPA	2270	102	4.5	12	0.5	0	0.0
VPI	2270	13	0.6	5	0.2	0	0.0
RRO	2042	50	2.4	18	0.9	0	0.0
ASF	9080	1226	13.5	219	2.4	8	0.08
ASM	4540	439	9.7	48	1.1	0	0.0
CSG	760	3	0.4	2	0.3	0	0.0
FS	2270	475	20.9	81	3.6	2	0.08
ATR	2270	178	7.8	23	1.0	1	0.04

Table 4  
Incidence of non-morphological (phonological, mixed and other) errors out of total responses

Subject	Stimuli ( <i>N</i> )	Phonological errors ( <i>N</i> )	Percentage	Mixed errors ( <i>N</i> )	Percentage	Other errors ( <i>N</i> )	Percentage
FAL	2270	153	6.7	16	0.7	43	1.9
LAN	2270	217	9.5	3	0.1	8	0.3
ABA	760	17	2.2	0	0.0	4	0.5
DBO	4540	588	12.9	48	1.0	82	1.8
FCA	760	15	2.0	1	0.1	3	0.4
ICA	2270	452	19.9	47	2.1	529	23.3
ECA	2270	300	13.2	62	2.7	758	33.4
MCE	760	53	7.0	1	0.1	3	0.4
ECO	1320	80	6.1	7	0.5	11	0.8
FDP	2270	120	5.3	3	0.1	19	0.8
PGA	2270	142	6.2	22	1.0	109	4.8
ALO	4540	173	3.8	21	0.5	105	2.3
MLO	760	68	8.9	0	0.0	2	0.3
GMA	2270	124	5.5	11	0.5	98	4.3
LMA	2270	40	1.8	0	0.0	9	0.4
GME	2270	36	1.6	0	0.0	2	0.1
AMO	2270	554	24.4	96	4.2	911	40.1
RPA	2270	43	1.9	1	0.04	3	0.1
EPA	2270	20	0.9	0	0.0	6	0.3
VPI	2270	95	4.2	1	0.04	2	0.1
RRO	2270	1092	53.5	94	4.6	200	9.8
ASF	9080	1273	14.0	260	2.9	796	8.8
ASM	4540	631	13.9	73	1.6	137	3.0
CSG	760	163	21.4	3	0.4	5	0.6
FS	2270	351	15.5	71	3.1	196	8.6
ATR	2270	121	5.3	7	0.3	80	3.5

Table 5

Cumulative incidence of morphological errors (collapsing across inflectional and derivational errors) and of phonological errors (collapsing across word and pseudoword errors) over total responses

Subject	Stimuli (N)	Morphological errors (N)	Percentage	Phonological errors (N)	Percentage
FAL	2270	185	8.1	153	6.7
LAN	2270	33	1.4	217	9.5
ABA	760	12	1.6	17	2.2
DBO	4540	223	4.9	588	12.9
FCA	760	21	2.8	15	2.0
ICA	2270	120	5.3	452	19.9
ECA	2270	253	11.1	300	13.2
MCE	760	12	1.6	53	7.0
ECO	1320	28	2.1	80	6.1
FDP	2270	120	5.3	120	5.3
PGA	2270	142	6.2	142	6.2
ALO	4540	317	7.0	173	3.8
MLO	760	0	0.0	68	8.9
GMA	2270	162	7.1	124	5.5
LMA	2270	24	1.0	40	1.8
GME	2270	17	0.7	36	1.6
AMO	2270	144	6.3	554	24.4
RPA	2270	62	2.7	43	1.9
EPA	2270	114	5.0	20	0.9
VPI	2270	18	0.8	95	4.2
RRO	2042	68	3.3	1092	53.5
ASF	9080	1453	16.0	1273	14.0
ASM	4540	487	10.7	631	13.9
CSG	760	5	0.6	163	21.4
FS	2270	558	24.6	351	15.5
ATR	2270	202	8.9	121	5.3

produce many morphological errors and no phonological errors.

### 3.5. Relative occurrence of morphological errors and of simple phonological errors resulting in nonwords

Thus far, we have considered incorrect word and incorrect nonword responses together when analyzing phonological errors. However, these two error types may have different causes. Phonologically related word responses could result from a lexical-level deficit, and hence would be an unreliable index of a phonological (segmental) processing deficit. Incorrect responses resulting in nonwords allow a more reliable estimate of a phonological disorder. For this reason, only phonologically related nonword responses that differed from the target by one or two phonemes were retained for further analyses. These simple phonological errors resulted in phoneme substitutions (e.g., *temiamo*, we hold → *\*lemiamo*), insertions (e.g., *partenza*, departure → *\*partrenza*), deletions (e.g., *spremere*, to squeeze → *\*spemere*) or transpositions (e.g., exchanges like *lavava*, he was washing → *\*valava*, and shifts like *riportare*, to bring again → *\*riprotare*). The occurrence of these errors relative to morphologically related responses was compared in each subject. Since derivational errors share on average fewer segments with the target than inflectional errors, and since the morphological error category conflated inflectional and derivationally related responses, the occurrence of

simple phonological errors was compared for each subject both with the occurrence of overall morphological errors and with the occurrence of inflectional errors only (Table 6).

The results of these analyses are similar to those reported in the previous section. No statistically reliable correlation was found between simple phonological errors and morphological errors (Pearson's  $r = 0.115$ ;  $P = \text{NS}$ ), nor between simple phonological errors and inflectional errors (Pearson's  $r = 0.101$ ;  $P = \text{NS}$ ). Some subjects who produced substantial numbers of morphological or inflectional errors (FS: 16 and 13.5%; ASF: 16 and 13.5%; ASM: 10.7 and 9.7%; ECA: 11.1 and 8.5%; FAL: 8.1 and 7.4%) also produced substantial proportions of simple phonological errors (FS: 5.9%; ASF: 6.3%; ASM: 9.7%; ECA: 4.9%; FAL: 3.8%). However, there are subjects like AMO, DBO and ICA, who produced the two types of errors with comparable frequency. And there are also subjects who made no or few morphological or inflectional errors (RRO: 3.3 and 2.8%; CSG: 0.7 and 0.4%; MLO: 0%), but produced many simple phonological errors (RRO: 19%; CSG: 13.8%; MLO: 8.3%). However, none of our subjects produced morphological errors but did not produce incorrect nonword responses.

### 3.6. The role of a phonological input deficit on repetition accuracy in our subject sample

Errors in a repetition task might arise not only from damage to an output mechanism, but also from an impairment at

Table 6

Occurrence of overall morphological errors (collapsing across inflectional and derivational errors), of inflectional errors and of simple phonological errors in each subject

Subject	Stimuli ( <i>N</i> )	Morphological errors ( <i>N</i> )	Percentage	Inflectional errors ( <i>N</i> )	Percentage	Simple phonological errors ( <i>N</i> )	Percentage
FAL	2270	185	8.1	167	7.4	87	3.8
LAN	2270	33	1.5	30	1.3	198	8.7
ABA	760	12	1.6	9	1.2	12	1.6
DBO	4540	223	4.9	193	4.3	435	9.6
FCA	760	21	2.8	18	2.4	9	1.2
ICA	2270	120	5.3	96	4.2	174	7.7
ECA	2270	253	11.1	193	8.5	111	4.9
MCE	760	12	1.6	8	1.1	35	4.6
ECO	1320	28	2.1	21	1.6	47	3.6
FDP	2270	120	5.3	98	4.3	75	3.3
PGA	2270	142	6.3	122	5.4	84	3.7
ALO	4540	317	7.0	276	6.1	106	2.3
MLO	760	0	0.0	0	0.0	63	8.3
GMA	2270	162	7.1	145	6.4	69	3.0
LMA	2270	24	1.1	18	0.8	17	0.7
GME	2270	17	0.7	15	0.7	14	0.6
AMO	2270	144	6.3	118	5.2	180	7.9
RPA	2270	62	2.7	56	2.5	31	1.4
EPA	2270	114	5.0	102	4.5	13	0.6
VPI	2270	18	0.8	13	0.6	84	3.7
RRO	2042	68	3.3	50	2.4	388	19.0
ASF	9080	1453	16.0	1226	13.5	574	6.3
ASM	4540	487	10.7	439	9.7	440	9.7
CSG	760	5	0.7	3	0.4	105	13.8
FS	2270	558	24.6	475	20.9	134	5.9
ATR	2270	202	8.9	178	7.8	82	3.6

the input level. Incorrect responses like *minestra*, soup → *finestra*, window, or like *tagliavo*, I was cutting → *tagliato*, cut, might result from activating an incorrect representation at the output level, but also from misperception of the input string. Since the purpose of the present study is to use repetition errors in order to draw inferences on the relationship between morphological and phonological information in spoken output, it must be shown that the patterns of performance observed in our subjects did not result from an input disorder.

To evaluate the possible role of a phonological input processing disorder, we compared the distribution of phonological and morphological errors produced by each aphasic participant in the repetition task to their performance on the phoneme discrimination task included in the screening battery for aphasia. In the latter task, subjects were asked to decide whether two meaningless CV syllables pronounced by the examiner, each consisting of a stop consonant (/p/, /t/, /k/, /b/, /d/, /g/) and of the vowel /a/, were the same ( $n = 30$ ) or different ( $n = 30$ ). In order to prevent lip-reading, the mouth of the examiner was hidden from the subject's view. Results are shown in Table 7. In the sample as a whole, no correlation was found between phoneme discrimination accuracy and overall number of errors (Pearson's  $r = 0.017$ ;  $P = \text{NS}$ ), overall morphological errors (Pearson's  $r = 0.152$ ;  $P = \text{NS}$ ), inflectional errors (Pearson's  $r = 0.138$ ;  $P = \text{NS}$ ) and simple phonological errors (Pearson's  $r =$

Table 7

Performance obtained by the subjects in the experimental sample on the CV syllable discrimination task included in the screening battery for aphasia (Miceli et al., 1994b)

Subject	Phoneme discrimination	Errors (%)
FAL	1/60	1.7
LAN	1/60	1.7
ABA	6/60	10.0
DBO	2/60	3.4
FCA	5/60	8.3
ICA	3/60	5.1
ECA	2/60	3.4
MCE	11/60	18.3
ECO	5/60	8.3
FDP	3/60	5.1
PGA	1/60	1.7
ALO	11/60	18.3
MLO	0/60	0.0
GM	5/60	8.3
LMA	2/60	3.4
GME	0/60	0.0
AMO	5/60	8.3
RPA	0/60	0.0
EPA	0/60	0.0
VPI	4/60	6.7
RRO	1/60	1.7
ASF	2/60	3.4
ASM	0/60	0.0
CSG	Not available	
FS	5/60	13.3
ATR	1/60	1.7

–0.178;  $P = \text{NS}$ ). This result rules out the possibility that poor phonological input processing was the direct cause for repetition errors in our subject sample.

It is possible, however, that the qualitative and quantitative aspects of repetition performance were affected to different extents, depending on the severity of input damage. To evaluate this possibility, subjects were assigned to three groups, based on their performance in the phoneme discrimination task. Subject CSG, who did not complete the latter task, was not included in this analysis. The first group included three subjects (ABA, MCE and ALO), who scored outside the normal range, as assessed in 20 control subjects, none of whom produced more than five incorrect responses. The second group included eight subjects (FCA, ICA, ECO, FDP, GM, AMO, VPI and FS), who presented with borderline normal performance—they scored within the normal range, but nonetheless made between three and five errors in phoneme discrimination. The third group consisted of the remaining 14 subjects, who made two or fewer errors, thus showing essentially flawless phonological input processing.

Table 8

Correlations between phoneme discrimination performance and the various error types, and correlation between simple phonological and morphological or inflectional errors in the entire sample, and in subjects with pathological, borderline or normal phoneme discrimination scores

	Pearson's $r$	$P$ -value
Pathological phoneme discrimination ( $n = 3$ )		
Phoneme discrimination vs. simple phonological errors	0.681	NS
Phoneme discrimination vs. morphological errors	0.500	NS
Phoneme discrimination vs. inflectional errors	0.485	NS
Simple phonological errors vs. morphological errors	–0.294	NS
Simple phonological errors vs. inflectional errors	–0.311	NS
Borderline normal phoneme discrimination ( $n = 8$ )		
Phoneme discrimination vs. simple phonological errors	–0.197	NS
Phoneme discrimination vs. morphological errors	0.248	NS
Phoneme discrimination vs. inflectional errors	0.264	NS
Simple phonological errors vs. morphological errors	0.335	NS
Simple phonological errors vs. inflectional errors	0.317	NS
Normal phoneme discrimination ( $n = 14$ )		
Phoneme discrimination vs. simple phonological errors	0.123	NS
Phoneme discrimination vs. morphological errors	0.389	NS
Phoneme discrimination vs. inflectional errors	0.338	NS
Simple phonological errors vs. morphological errors	0.038	NS
Simple phonological errors vs. inflectional errors	0.018	NS

For each group, the correlation between phoneme discrimination performance and the occurrence of simple phonological, morphological and inflectional errors was evaluated, as well as the correlation between the occurrence of simple phonological errors and that of morphological and inflectional errors (Table 8). Even though the values for the first two groups must be taken with caution, due to small group size ( $n = 3$  and 8, respectively), all the comparisons were very far from being statistically significant. The performance of the 14 aphasics with normal input processing is of particular interest, as the errors produced by these subjects are most likely to result from damage to output mechanisms. There was, once again, no correlation between morphological and phonological errors (Pearson's  $r = 0.018$ ;  $P = \text{NS}$ ). The distribution of inflectional and simple phonological errors in this selected subgroup (Fig. 1) clearly shows that most subjects produce both types of incorrect responses to comparable extents, and that in a small number of cases segmental errors are far more frequent than inflectional errors. However, it fails to demonstrate the reverse dissociation, namely the selective occurrence of morphological errors in the absence of phonological errors.

#### 4. Discussion

In this project, a large sample of Italian-speaking aphasic subjects, selected because they produced morphological errors in one or more of the single-word processing tasks included in an aphasia screening battery, were asked to repeat words and pseudowords. The goal of the study was to verify if the co-occurrence of morphological and phonological errors is as systematic as suggested by a review of the single-case reports in the literature, and to evaluate the implications of this phenomenon for neuroanatomical and functional theories of speech production. Finding, as in previous reports, that subjects who produce morphological errors also make segmental errors would favor hypotheses suggesting a tight functional and/or neuroanatomical correlation between the two types of processes. By contrast, dissociations between the two error types would encourage considering morphological and segmental processes as functionally and anatomically distinct.

The facts that emerged from the reported analyses can be summarized straightforwardly. A very high correlation was observed between performance accuracy on words and pseudowords, and between the frequency of occurrence of inflectional and derivational errors (the former were always more numerous than the latter, probably due to the properties of the inflectional and the derivational system in Italian (see Section 3.2); but subjects who made the largest numbers of inflectional errors also made relatively large numbers of derivational errors). However, and crucially for our current purposes, there was no correlation between the frequency of morphological and phonological (segmental) errors. This was true when we collapsed across inflectional and

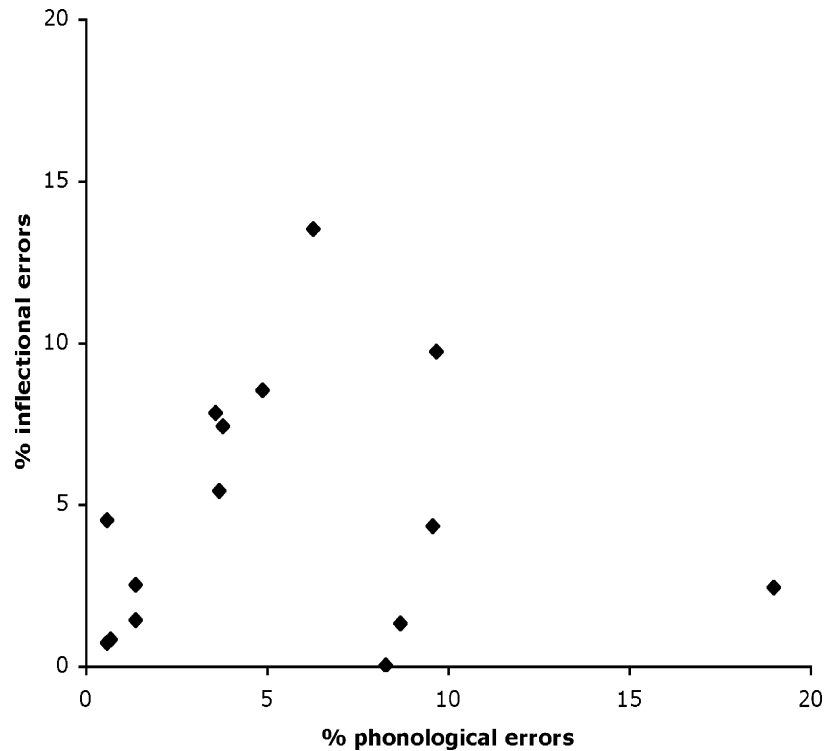


Fig. 1. Occurrence of inflectional errors and of segmentally incorrect pseudowords in subjects with normal phonemic input processing.

derivational errors, and across phonologically related word and pseudoword responses; it was also true when the analysis was restricted to inflectional errors and phonologically related pseudowords. Such lack of correlation was observed in the whole sample and, more importantly, in the subgroup of subjects with normal phonological input processing, whose errors can be taken to reflect a production deficit.

At face value, failure to find a significant correlation between morphological and phonological errors would seem to suggest that the morphological and phonological processes involved in spoken output are independent. However, a closer scrutiny of the data indicates that such independence is asymmetrical. As shown in Table 6 and in Fig. 1, our sample includes many aphasics who produced comparable numbers of phonological and inflectional errors (e.g., ASM: 9.7 and 9.7%; AMO: 7.9 and 5.2%; ICA: 7.7 and 4.2%, respectively), and a small number of subjects who produced large numbers of phonological errors, but very few (or no) inflectional errors (e.g., RRO: 19 and 2.4%; CSG: 13.8 and 0.4%; MLO: 8.3 and 0%, respectively). However, in agreement with previous reports, none of our aphasic speakers presented with the reverse pattern of performance—large numbers of morphological errors in the absence of phonological errors.

The observation that all subjects who produced morphological errors also produced phonological (segmental) errors, and that there was no statistical correlation between the two error types can be accommodated by a neuroanatomical account—the neural structures involved in morphological

processes overlap (at least partially) with those involved in phonological processes. This possibility is suggested by neuropsychological and neuroimaging data, which point to the left inferior prefrontal cortex as a crucial area with regard to both morphological and phonological processes. In the first place, this portion of the left hemisphere is frequently damaged in subjects with so-called agrammatic aphasia, who almost invariably produce morphological errors in spontaneous speech (Mohr et al., 1978; Vanier & Caplan, 1990). In our study, the left inferior prefrontal cortex was impaired in 13/19 subjects (68.4%) who produced morphological errors in the single-word processing tasks of the screening battery, and for whom neuroradiological documentation was available. Secondly, neuroimaging studies provide independent evidence suggesting that the left inferior prefrontal cortex is functionally heterogeneous. Recent PET and fMRI investigations show that neural networks located in this region are active during phonological, semantic, syntactic and working memory tasks (Dapretto & Bookheimer, 1999; Fiez, 1997; Friederici, Opitz, & von Cramon, 2000; Paulesu et al., 1997; Poldrack et al., 1999; Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). More specifically, an involvement of the left inferior prefrontal cortex in processing the grammatical and phonological properties of words is suggested by a recent fMRI study (Miceli et al., 2002). When normal subjects were asked to respond to a grammatical property (grammatical gender) or to a phonological property (the presence of a /k/ or a /tch/ sound) of the same nouns, activation was observed in contiguous areas of the left

inferior prefrontal cortex (areas BA 44 and 45, respectively). On this account, then, damage to the left inferior prefrontal cortex necessarily results in a mixture of morphological and phonological errors.

This pattern should be observed even if morphological and phonological processes were functionally independent, as assumed by most theories of language production. The distinction between morphology and other aspects of speech is supported by studies of slips of the tongue in normal subjects (e.g., Garrett, 1980). In errors like “I thought the *park* was *trucked*” (for “I thought that the *truck* was *parked*”) two root morphemes exchange positions in the sentence frame, whereas the inflectional morpheme is “stranded” in the correct slot, suggesting that stems and suffixes are processed by at least partially distinct mechanisms. On this view, producing a morphologically complex word involves activating stem and inflectional morphemes, which are then combined in a morphologically complex string, syllabified, and transformed into a phonologically specified sequence. Theories of this type (e.g., Garrett, 1980; Levelt, 1989) would predict that, on occasion, morphological and phonological processes should be affected independently. The lack of case studies supporting such dissociation might stem from the anatomical proximity of the neural structures involved in the two sets of processes. The relative prevalence of one or the other error type in a subject might result from more extensive damage to neural tissue involved in morphological or in phonological processes. The selective occurrence of segmental errors in some subjects might result from the fact that whereas morphological processes take place mostly in the left inferior prefrontal cortex, segmental processes involve other neural structures as well. Consistent with this possibility, several neuropsychological investigations of conduction aphasia (Benson et al., 1973; Cappa, Cavallotti, & Vignolo, 1981; Damasio & Damasio, 1980; Quigg & Fountain, 1999) and neuroimaging studies (Hickok et al., 2000; Wise et al., 2001) suggest that segmental processes involve extensive portions of the left perisylvian cortex beyond the left inferior prefrontal cortex, and especially the posterior and superior aspects of the temporal lobe.

An alternative account for the same phenomenon relies on the functional inseparability of morphological and phonological processes, as assumed by interactive theories of speech production. In some such models (e.g., Dell, Schwartz, Martin, Saffran, & Gagnon, 1997; Stemmer, 1985), spoken output involves extensive, bidirectional exchange of information between the lexical and the segmental layer: the lexical layer spreads activation downstream to the segmental layer which, in turn, sends activation back to the lexical layer. This bidirectional interaction eventually results in the selection of the target lexical node and subsequently in the selection of its segmental content. Because of the interactivity between levels of representation, damage to any part of the system will necessarily result in various mixtures of phonological (word and pseudoword) and lexically based errors (see Dell et al., 1997 for discussion of

the related case of the occurrence of mixtures of semantic and phonological errors in naming; but see Rumel & Caramazza, 2000 for an alternative view). This model has not yet been developed to include morphological processing; hence, even though extensive interaction between the lexical and segmental layer clearly predicts a very high correlation between morphological and phonological errors in the case of morphologically complex words, any conclusion must be tentative.

Another proposal has focused on the production of the English past tense (Joanisse & Seidenberg, 1999). The model includes a semantic layer that represents verb meaning and a “past tense” feature, and a speech output layer responsible both for retrieving the corresponding lexical representation and for assigning its segmental content. On this view, producing the past tense of regular and irregular verbs does not require separate mechanisms—contrary to the assumption of “dual-route” theories, which propose that regular forms are rule-generated, whereas irregular forms are autonomously represented in the lexicon (e.g., Marslen-Wilson & Tyler, 1997; Pinker, 1991). Activating the “past tense” feature in the semantic system and the corresponding phonological representation in the output component ensures production of the correct form for both regular and irregular verbs. However, the semantic component is weighted differently in the two cases: it plays a critical role only in the case of irregular verbs. This is assumed to compensate for the fact that there is less phonological overlap between present and past forms of irregular as opposed to regular verbs. Given this type of architecture, damage to the semantic layer results in greater difficulty in producing irregular forms, whereas damage to the speech output layer mostly affects regular forms. Since the output layer in this model serves both for retrieving the target lexical entry and for establishing its phonological content, a strong correlation between morphological and phonological errors is expected. And, in fact, when the model’s task was to produce the past tense of nonce verbs, errors resulted in selecting *phonologically related* roots (10% of total responses produced by the simulation). However, our results are at variance with this prediction, since the observed correlation between inflectional and segmental errors was extremely low (for a criticism of this model based on a different type of evidence, see Miozzo, 2003). Be this as it may, whether interactive models will be able to accommodate the various mixtures of morphological and phonological errors reported here cannot be decided until specific simulations are carried out.

Although the co-occurrence of phonological and morphological errors can be explained within various theoretical frameworks, not all these accounts fare equally well when we consider the additional fact that some patients who make phonological errors make no morphological errors at all. The theories that assume that morphological and phonological processes are interactive predict that subjects who

produce phonological errors should also make morphological errors. By contrast, those theories that assume functional independence of morphological and phonological processes allow for the occasional occurrence of a dissociation between phonological and morphological errors. (Of course, “morphological” errors should occasionally be observed even when the cause of the errors is phonological in nature simply by chance. For example, changing a *v* into a *t*, and an *i* into an *a* results in phonological errors in the case of *vino*, wine → *тино*, barrel, and of *viso*, face → *vaso*, flowerpot, but in morphological errors in the case of *davo*, I was giving → *dato*, given, and of *alti*, tall, m.pl. → *alta*, tall, f.sg.) Consistent with the prediction of the latter type of theories, two fluent aphasics produced almost exclusively segmental errors when repeating morphologically simple words (but they also produced several morphological errors when repeating polymorphemic words) (Kohn & Melvold, 2000). A similar error pattern was observed in three “conduction” aphasics tested during the present project, who did not produce morphological errors for the morphologically complex words included in the screening battery, but made several errors of this type on the more extensive Lexical Morphology Battery (e.g., subject IFA produced 831/2270 segmental errors, or 36.6%, but also made 94/2270 morphological errors, or 4.1%). Some subjects, however, do not show the predicted pattern. Our case MLO produced many pseudowords (8.3%), but no morphological errors;<sup>1</sup> and the same profile was observed in three conduction aphasics suffering from damage to the left post-rolandic perisylvian regions (Caplan et al., 1986; Caramazza et al., 2000; Wilshire & McCarthy, 1996), who produced exclusively incorrect pseudoword responses.

The selective occurrence of segmental errors in the absence of morphological errors, observed in a small number of aphasic subjects, might result from the fact that transforming a lexical phonological representation into spoken output is a complex process (e.g., Caplan, 1992; Levelt, 1989). Among other things, it involves selection of abstract phonological segments, phonological adjustments, syllabification, the coding of more basic properties such as degree of sonority and articulatory features, and finally the transfer of this information to the effectors for spoken output. The processing of these various aspects of speech might be at least in part carried out by functionally and neuroanatomically distinct processing mechanisms. If the more abstract

phonological processes were implemented primarily in neural regions contiguous to (or intertwined with) those involved in morphological processes, whereas more peripheral mechanisms of spoken output were represented mostly in distinct regions of the left hemisphere, damage to the former would result in the co-occurrence of segmental and morphological errors, whereas an impairment of the latter would yield only phonological errors.

To conclude, the observation that in our sample all the subjects who produced morphological errors also made phonological errors confirms previous reports and suggests a very close relationship, either neuroanatomical or functional, between morphological and segmental processes. For the time being, an account based on the contiguity of the neural structures involved in functionally distinct morphological and segmental processes seems more promising than one based on the extensive functional interaction between the two types of processes. The failure to document selective morphological damage in our sample only licenses the conclusion that the available empirical evidence does not yet allow such distinction—it does not warrant the conclusion that morphological and phonological processes are indistinguishable. Perhaps, failure to report the critical dissociation in our sample might be due to the fact that a repetition task is not sufficiently demanding to allow for the evaluation of subtle morphological deficits. Had we used, say, a task requiring morphological transformations, the relevant pattern might have been found. And, in fact, there are suggestions that morphological processes may be selectively affected by brain damage. Our subject EPA, who presented with extensive damage to the left inferior prefrontal cortex and was a classical “agrammatic” speaker, produced many morphological (5%) and particularly inflectional (4.5%) errors, but very few (0.6%) phonological errors. Deep dyslexic subject HH (Laine et al., 1995) suffered from a number of cognitive deficits (involving input and output lexical components, as well as the semantic system), any of which may have been responsible for his morphological errors, but produced very few segmentally incorrect responses. Subject RGB (Caramazza & Hillis, 1990), who presented with a fronto-parietal infarct and was not agrammatic, produced some morphological errors but no segmental errors in a delayed repetition task. Based on these observations, it would not be surprising to find a subject who produces morphological but not phonological errors as a consequence of damage to lexical output mechanisms.

## Acknowledgements

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<sup>1</sup> During the screening procedure this subject produced very few morphological errors and several segmental errors in single-word production tasks, and also produced some inflectional (agreement) errors in spontaneous speech. However, and contrary to expectations, he did not make morphological errors in the repetition tasks. We have no ready explanation for this unexpected behavior. It is possible that MLOs “inflectional” errors produced during the screening procedure were phonologically, not morphologically based. It is also possible that the morphological disorder in this subject was sufficiently mild to show in complex morphosyntactic tasks such as spontaneous speech, and not in morphologically less demanding tasks, such as single-word repetition (see also the last paragraph in this section).

## Appendix A

Structure of the three blocks of stimuli used to evaluate morphological disorders in repetition.

### A.1. Block 1 ( $n = 760$ stimuli)

- (a) *Derived and non-derived words*: This sublist consisted of 270 derived and inflected words and of 270 non-derived, inflected words (all Italian words are inflected). Stem frequency of derived words was matched with root frequency of inflected words. There were 300 nouns, 140 adjectives and 100 verbs. For each grammatical category, half of the stimuli were derived, half were non-derived.
- (b) *Verb forms*: This sublist included 150 verb forms, controlled for root and form frequency. There were 50 high-frequency forms of verbs with high-frequency roots; 50 low-frequency forms of verbs with high-frequency roots (half of these were the same high-frequency verbs, half were different high-frequency verbs); and 50 low-frequency forms of verbs with low-frequency roots.
- (c) *Function words*: This sublist was comprised of 35 inflected functors (deictic terms, preposition + determiner combinations, indefinite adjectives) and 35 uninflected functors (adverbs and prepositions).

### A.2. Block 2 ( $n = 760$ stimuli)

- (a) *Derived words contrasting for form frequency*: This sublist included 50 derived words with high-frequency forms and 50 derived words with low-frequency forms. There were overall 36 nouns, 34 verbs and 30 adjectives. Items were matched for length.
- (b) *Derived and non-derived verbs*: This list included 50 derived verbs and 50 non-derived verbs, matched for root frequency and for length.
- (c) *Evaluative suffixes*: This list was comprised of 30 words with evaluative suffixes, and 30 non-derived words, matched for form frequency and length.
- (d) *Constellation of derived words*: This sublist contained 15 nouns, and words derived by prefixation or suffixation from these 15 nouns. Overall, it included 200 stimuli.
- (e) *Prefixed and suffixed words*: This list included 50 prefixed and 50 suffixed words, matched for stem and form frequency, and for length. Stimuli in the two sets were also matched for length of prefix or suffix.
- (f) *Pseudowords with and without morphological structure*: This sublist included 200 pseudowords. Half of these could be parsed into an illegal combination of verb root + verb inflection. The remaining half, which could not be similarly parsed, were obtained by changing one or two phonemes from an existing word. Stimuli of the first type corresponded to sequences like \**temava*, which results from the illegal combination of the second conjugation root *tem-* (from the verb *temere*, to be afraid of)

with the first conjugation inflection *-ava* (third singular, imperfect indicative). Stimuli of the second type consisted of strings like \**pefrolio*, resulting from the substitution of a phoneme in the word *petrolio*, oil. The frequency of the verb roots used to construct morphologically complex pseudowords was matched with the frequency of the words used to construct pseudowords without morphological structure.

### A.3. Block 3 ( $n = 950$ stimuli)

- (a) *Prefixed and pseudoprefixed words*: This sublist consisted of 160 stimuli, belonging to different word categories. It included 50 prefixed words (7 nouns, 8 adjectives and 35 verbs), 50 pseudoprefixed words (26 nouns, 9 adjectives and 15 verbs) and 60 filler words (28 nouns, 11 adjective and 21 verbs). Words in the three sets were matched for length and form frequency.
- (b) *Inflected and pseudoinflected words*: This sublist included 100 words, half inflected (all verbs), half pseudoinflected (32 nouns and 18 adjectives). Stimuli in the two sets were matched for length and for form frequency.
- (c) *Derived and pseudoderived words*: This list consisted of 100 stimuli. Of these, 50 were derived (28 nouns and 22 adjectives), and 50 were pseudoderived (35 nouns and 15 adjectives). Derived and pseudoderived words were matched for form frequency and length.
- (d) *Root and inflection frequency*: This sublist was comprised of 120 verb forms. To make up this list, 40 verbs with high-frequency roots and 40 verbs with low-frequency roots were selected, as well as 40 high-frequency inflections and 40 low-frequency inflections. Each verb root was paired with a high-frequency inflection and with a low-frequency inflection. Thus, this sublist consisted of verb forms resulting from the combination of HF root + HF inflection, of HF root + LF inflection, of LF root + HF inflection and of LF root + LF inflection ( $n = 40$  each).
- (e) *Homophonic stems*: This sublist included 60 words. There were 15 pairs of words with homophonous stems (e.g., *albo*, album; *alba*, dawn;  $n = 15$ ), and 15 pairs of phonologically similar words, used as controls (e.g., *bolla*, bubble; *molla*, spring;  $n = 15$ ).
- (f) *Phonologically transparent and opaque derivation*: This sublist included 100 derived words. In 50 of these, the stimulus was derived through a phonologically transparent process (*altezza*, height, from *alto*, tall); in the remaining 50 words, the stimulus was semantically transparent, but phonologically opaque (*bontà*, goodness, from *buono*, good). Both sets contained 20 nouns, 27 adjectives and 3 verbs. Words in the two sets were matched for length and form frequency.
- (g) *Semantically transparent and opaque derivation*: This sublist list included 100 derived words. In all cases, the derivational process was phonologically transparent, but in 50 words the relationship between root and stem was

semantically opaque (*artiglieria*, artillery, from *artiglio*, claw) whereas in the remaining 50 it was semantically transparent (*frutteria*, fruit shop, from *frutta*, fruit).

- (h) *Regular and irregular verb forms*: This sublist consisted of 50 regular forms of verbs with an irregular sub-paradigm, of 50 irregular forms of the same verbs, and of 50 forms of regular verbs. Stimuli were matched for form and root frequency.
- (i) *Compounds*: This sublist consisted of 30 compound words and of 30 filler words, matched for length and form frequency.

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