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Processing Inflectional and Derivational Morphology

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Three lexical decision experiments were carried out to investigate the nature of morphological decomposition in the lexical system. The first of these experiments compares the priming effect of inflectionally and derivationally related forms on a simple inflected word. Italian derived words like *mutevole* (changeable) were as effective as non-derived inflected words like *mutarono* (they changed) in priming the related form *mutare* (to change). The design of the remaining experiments is based on the stem homograph paradigm (Laudanna, Badecker, & Caramazza, 1989, *Journal of Memory and Language*, **28**, 531–546). When an unambiguous word like *mute* (mute) is primed by a stem homograph like *mutarono* (they changed)—a morphologically unrelated word with a homographic stem—there is a robust inhibitory effect when compared with unrelated prime conditions. Experiments two and three compared the effect on forms like *mute* of priming by an inflected stem homograph (*mutarono*) and priming by a derived "root homograph" like *mutevole*—a morphologically unrelated derived word with a homographic root (*mut-*). While there was a consistent inhibitory effect with the inflected primes, there was no such effect with the derived primes. These results indicate that there is a level of lexical representation in the input lexicon at which inflected and derived words are analyzed in terms of their inflectional stems and affixes, but not also in terms of their derivational roots and affixes. It is argued that the inhibitory effects found in experiments two and three and the facilitation effects found in experiment one and elsewhere support the notion that there are multiple representational levels at which morphological structure is represented.

In previous research (Laudanna, Badecker, & Caramazza, 1989), we have found evidence for inhibitory priming between stem homographs. Stem homographs are words with stems that are orthographically identical, but semantically and morphologically unrelated (e.g., Italian *colp-a* "guilt" and *colp-o* "blow"). It was shown that lexical decisions were more difficult for a word like *colp-o* when paired with (or preceded by) a stem homograph (*colp-a*) than when paired with an unrelated word (e.g., *pont-e* "bridge") or with an orthographically similar form (e.g., *coll-o* "neck"). This inhibitory effect was interpreted within the Augmented Addressed Morphology (AAM) model of lexical processing (Caramazza, Miceli, Silveri, & Laudanna, 1985; Caramazza, Laudanna, & Romani, 1988) as the result of a relation between stems (as opposed to orthographically similar whole-word representations) in the input lexicon. Specifically, it was argued that the activation of the stem entry ⟨*colp-*, N, masc., . . . ⟩ for *colpo* interferes with the subsequent attempt to activate the orthographically identical stem entry

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⟨*colp-*, N, fem., . . . ⟩ for *colpa*.[1] This interference was hypothesized to reflect the lexical system's response to the recognition problem posed by having two entries with the same form: If only one word is appropriate to a particular context, but the lexicon has at least two grammatically distinct entries whose form matches that of the stimulus, then some mechanism must suppress the grammatically inappropriate entry. What makes this an argument for morphological decomposition is that the relevant items are homographs only when their inflectional endings are ignored. Word pairs that had the same degree of orthographic overlap but did not have identical stem forms (e.g., *collo/colpo*) did not induce the inhibition. Hence, it would appear that the effect must take place at a level of processing (the orthographic input lexicon) where lexical forms are represented in terms of their constituent morphemes: stems and inflections.

In the research reported here, we have extended the stem homograph paradigm in order to study the effect on an inflected form (e.g., *mute* "mute (fem.pl.)") induced by a derived form with a homographic root (e.g., *mutevole* "changeable") in comparison with an inflected form with a homographic root (e.g., *mutarono* "they changed"). The sequence *mut-* is the morphological root of both *mutarono* and *mutevole*, whereas the inflectional bases (or stems) of these two words are *mut-* and *mutevol-*, respectively. The issue addressed in this study is whether both inflected and derived words have their internal structure specified in terms of their morphological roots (which we will refer to as the root representation hypothesis) or if, instead, the morphological form that is accessed is the inflectional base (the stem representation hypothesis).[2] Both the *root* and *stem* representation hypotheses posit morphologically decomposed entries in the input lexicon, but they differ as to the units of representation of the entries themselves. The present study is composed of three visual lexical decision experiments in which the effects of inflectional and derivational relations on root homographs are compared. By inflectional relation, we refer to the morphological association which obtains between two inflected forms of the same root (e.g., *mutarono* "they changed" and *mutare* "to change"); and by derivational, that which holds between pairs of derived and inflected words sharing the same root (e.g., *mutevole* "changeable" and *mutare* "to change").

The experiments are based on the following assumptions. According to the root representation hypothesis, derived words are represented in the input lexicon as root plus derivational suffix plus inflectional suffix (e.g., *mutevole* becomes ⟨*mut-*, V, . . . ⟩ + ⟨*-evol-*, Adj, V]—, . . . ⟩ + ⟨*-e*, A]—, . . . ⟩). When presented as a prime for a root homograph, the root component of this complex representation should exert the same inhibitory effect on the root of an inflected form as observed in the case of inflected stem homographs (e.g., *mut-arono*). That is, both *mut-evol-e* and *mut-arono* should render the lexical decision for *mut-e* more difficult, because both activate the homographic root *mut-*. On the other hand, the stem representation hypothesis is based on the assumption that the lexical representation for a derived word consists of its stem plus inflection information. Hence, *mutevole* would access the entries ⟨*mutevol-*, Adj, . . . ⟩ + ⟨*-e*, A]—, . . . ⟩. On this account,

[1] We represent entries in the orthographic input lexicon in terms of an ordered sequence whose first element is the orthographic form, followed by the grammatical features (e.g., N = noun; masc. = masculine; and so forth) associated with that form.

[2] Whether inflectionally and derivationally affixed words are lexically represented in decomposed form is independent of the issue of how these composite representations can be accessed. That is, we are not arguing that an inflected word must be parsed prior to access, since the same (decomposed) entry may be accessed by means of a whole-word address procedure (see Caramazza et al., 1988, for detailed discussion).

no interaction between the entries ⟨*mutevol-*, Adj, . . . ⟩ and ⟨*mut-*, Adj, . . . ⟩ is predicted: The inhibitory effect seen with (inflectional) stem homographs (i.e., the effect of *mutarono* "they changed" on *mute* "mute (fem.pl.)") should not occur when *mutevole* (changeable) is used to prime *mute*.

While the *root* and *stem* representation hypotheses differ as to their predictions regarding the effect of priming by root homographs, they do not make clearly divergent predictions concerning the priming effect of derived and inflected words that are morphologically (semantically) related to the target. Stanners, Neiser, Hernon, and Hall (1979) and Fowler, Napps, and Feldman (1985) found that when a monomorphemic word like *pour* is primed by an inflectionally related form (e.g., *poured, pouring, pours*), there is a facilitatory effect on lexical decision that is as robust as what is found when the word *pour* is primed by a presentation of *pour* itself. The same sort of priming by a regularly inflected form was found in the auditory modality by Kempley and Morton (1982). Stanners et al. (1979) also reported that there is facilitation when a base form like *select* is primed by a derivationally suffixed form (e.g., *selective*), although they found that priming in this instance is not as effective as identity priming (i.e., priming by *select*). However, when Fowler et al. (1985) increased the number of items intervening between prime and target, they found that both the inflectionally and derivationally suffixed words like *detached* and *detachment* prime their base form (*detach*) as effectively as the base form primes itself. Morpheme and identity priming have both been interpreted as the result of repeated activation of a unit of processing, and under this construal the morpheme priming effects cited above may be understood as indicating that inflectional and derivational morphology are treated alike by lexical access mechanisms. Alternatively, morpheme priming may be the combined product of a number of representational or processing levels, including processes at morpho-semantic levels of representation (i.e., at a level of processing that is subsequent to the recognition of the morpho-phonological or the morpho-orthographic form of a word). Hence, even if the stem representation hypothesis is correct with regard to the processing units of the orthographic input lexicon, one could still observe repetition priming of an inflected form like *mutare* (to change) by a morphologically related derived form like *mutevole* (changeable).

In what follows, three experiments are reported. All of the test items in the experiments are root or stem homographs. That is, for each item like *mutarono* "they changed" or *mutevole* "changeable," there is a morphologically unrelated root/stem homograph (*mute* "mute" in our example). In order to create a set of experimental stimuli that are comparable to those used in previous root priming experiments, we imposed the following stimulus conditions in all three of the experiments discussed here: (1) the roots of the derived words (e.g., *mut-evole*) do not differ phonologically (or orthographically) from the roots of either their base forms or their root homographs (in this case, *mut-are* and *mut-e*, respectively); (2) the derivational suffixes are highly productive; and (3) the relation between the derived form and its base is semantically transparent. If, in fact, only some derived words access entries corresponding to their root, then these are the best candidates.

Experiment 1

The objective of the first experiment was to investigate whether a derived word like *rapitore* (abductor) is as effective as the inflected form *rapivano* (they abducted) in priming *rapire* (to abduct). This issue was addressed by directly comparing lexical decisions on the same target preceded either by an inflectionally related form (condition I-I), a derivationally related form (condition D-I), or an unrelated form (condition U-I;

e.g., *limpido* "limpid" priming *rapire*). It should be noted that a positive finding in this experiment would not discriminate between the root representation hypothesis and the stem representation hypothesis, because they both predict (or are both able to explain) facilitatory effects in conditions I-I and D-I.

Method

Subjects

Sixty subjects from the University of Rome, all native speakers of Italian, took part in the experiment. All subjects participated as volunteers and were paid for their participation.

Stimuli

Ten target words containing a homographic root were selected. For example, the target item *rapire* "to abduct" has a root that is homographic with the root of *rapa* "turnip": in both cases it is ⟨*rap-*⟩. Each of these target words appeared three times in the experimental list: once preceded by an inflectionally related word containing the same root (e.g., *rapivano* "they abducted," Category I-I); once preceded by a derivationally related word containing the same root (e.g., *rapitore,* "abductor," Category D-I); and once preceded by a word that was neither semantically nor orthographically related (e.g., *limpido,* "limpid," Category U-I). In all, 30 pairs of experimental stimuli were selected, equally subdivided among the three experimental categories. The mean word frequency of the 10 target stimuli was 63; the mean root frequency was 122 (Bortolini, Tagliavini, & Zampolli, 1971). The list of target words was composed of six verbs and four nouns, with a mean length of 6.1 letters. The number of letters in common among the paired prime and target items was 4 and 4.1 for categories I-I and D-I, respectively.

The derivational suffixes of the primes in stimulus category D-I were among the most productive in Italian. The primes included four items with the adjectival suffix *-evole* (approximately translated as the English suffix *-able*), four items with the agentive, nominalizing suffix *-tore* (cf. English *-er*), and two items with the nominalizing suffix *-mento* (which corresponds to the English suffix *-ment*).

In order to avoid repeating the target words during the experimental session, each list of prime–target pairs was split into three sublists (one set of four pairs and two sets of three pairs). Each subject was presented with a composite list of prime–target pairs comprised of one sublist from each of the three experimental conditions, for a total of 20 experimental stimuli (10 primes and 10 targets) in which no item was repeated. Three subjects presented with three complementary composite lists represented a single point for statistical analysis.

In addition to the test items, each individual subject was also presented with 90 filler word targets (preceded on 40 occasions by a word prime, and on 50 occasions by a nonword prime) and 100 non-word targets (equal numbers of which were preceded by word and nonword primes), for a total of 200 stimuli pairs. The only repeated roots in the complete list of test and filler items were those in the prime–target pairs of categories I-I and D-I. All of the other roots appeared only once. The 180 filler words consisted of 90 nouns, 54 verbs, and 36 adjectives.

The 200 nonwords in the list were obtained by changing one or two letters from real Italian words in accord with the graphotactic constraints of the language. The letters were changed 67 times each in the initial and final third of the base word, and 66 times in the medial third of the base word. The 200 base words for the nonwords were matched by item in length, form class, and approximate frequency with 200 words randomly selected from the corpus of 220 experimental and filler words in the list. Seven nonword targets in the list were preceded by an orthographically similar word or nonword prime. This number was equal to the total number of I-I and D-I pairs that each subject saw, so that these nonword stimuli should counteract any tendency to develop a strategic bias based on the observed morphological relatedness of the I-I and D-I pairs.

Materials and Equipment

The stimuli appeared on a video display unit controlled by an Apple II personal computer.

Procedure

The experimental sequence was as follows. At the beginning of the experimental sequence, subjects heard a brief tone, which was followed after 600 ms with the presentation of a fixation point ("+") at the center of the screen. After 400 ms the fixation point disappeared and was replaced, after 200 ms, by the prime stimulus. The prime stimulus appeared in the center of the screen for a period of 150 ms, and it was followed, after a 50 ms interval, by the target stimulus.

Subjects were instructed to make the lexical decision, on the target item only, by pushing one button, when they considered the presented target to be a word, and another, when the target stimulus was considered a nonword. They were also instructed to be as fast and as accurate as possible. If subjects did not provide a response before a preset limit of 1 s, the stimulus disappeared and the words "piu‘ veloce" (quicker) appeared in the upper right corner of the screen. When subjects gave the wrong response, the word "errore" (error) appeared; when they gave the correct response, the reaction time (in milliseconds) was displayed on the upper right corner of the screen after the disappearance of the stimulus. Response time or error feedback was shown on the screen for 1 s. The intertrial interval between the disappearance of the feedback information and the warning tone for the next trial was fixed and lasted 1 s.

The 200 stimulus pairs seen by each individual subject were arranged in three different random orders and subdivided into four blocks of 50 pairs each. No experimental pair was included among the first four pairs in a block. The rest interval between blocks was 1 min. Before the experimental session, subjects were presented with a practice list of 40 stimulus pairs arranged in two blocks of 20 each. The practice trials had the same characteristics as those which comprised the experimental list.

Results

Mean RTs and percentages of errors for the three experimental conditions are reported in Table 1. Analyses of variance, by subjects and by items, were carried out for the reaction time and error data. Targets with inflectionally related primes (condition I-I) were responded to 26 ms faster than control targets (condition U-I); while responses for the targets with derivationally related primes (condition D-I) were 35 ms faster than control targets. A main effect of experimental conditions was found on reaction times by subjects ($F(2,57) = 6.03, p < 0.005$) and by items ($F(2,27) = 4.67, p < 0.02$), with Min F approaching significance: Min $F(2,76) = 2.63, p < 0.09$. Analysis on errors did not show effects of experimental conditions by either subjects ($F(2,57) =$

TABLE 1
EXPERIMENT 1

	Inflected prime/ inflected target (I-I) e.g., *rapivano/rapire*	Derived prime/ inflected target (D-I) e.g., *rapitore/rapire*	Unrelated prime/ inflected target (U-I) e.g., *limpido/rapire*
RT	597	588	623
% errors	7.0	11.0	11.5

1.56, $p > 0.20$) or items ($F(2,27) = 0.95$). Additional planned comparisons were carried out with Duncan's test in order to evaluate the hypothesized priming by inflectionally and derivationally related words. The results of these tests, performed on the basis of subjects' variance, indicated that decision latencies for inflectionally and derivationally primed items were significantly faster than for the targets in the control condition (I-I vs. U-I: $t(k = 2) = 3.64$, $p < 0.02$; D-I vs. U-I: $t(k = 3) = 4.90$, $p < 0.005$). Furthermore, no reliable difference was found between categories I-I and D-I ($t(k = 2) = 1.26$).

The results of this experiment indicate that inflectionally and derivationally related primes induce the same degree of facilitation on their targets. However, when we consider that the prime–target stimuli in conditions I-I and D-I are not only related morphologically, but also at the levels of semantics and orthography, it can be seen that this finding is compatible with both the root and stem representation hypotheses. To recapitulate, the root representation hypothesis holds that lexical recognition for complex words like *rapitore* "abductor" involves access to the root ⟨*rap-*⟩ morpheme representation; while for the stem representation hypothesis, only stem (⟨*rapitor-*⟩) and inflection information is represented in the lexicon. The results of Experiment 1 are ambiguous because the mechanism of facilitation is underspecified. For the root representation hypothesis, the processing of inflected words (e.g., *rapire* "to abduct") preceded by inflectionally or derivationally related forms may be primed by the previous access to lexical root information (*rap-* in this example). According to the alternate, stem representation account, priming of *rapire* by the derived form *rapitore* occurs because of the semantic relatedness of the two words. That is, priming occurs despite the fact that access to this semantic information, for example, is achieved by way of the entry ⟨*rap-*⟩ in the former case and the entry ⟨*rapitor-*⟩ in the latter. What is needed to distinguish these accounts is a technique that clearly distinguishes morphological levels of analysis from semantic and orthographic levels of processing. One candidate is the stem homograph priming paradigm introduced in Laudanna et al. (1989).

Experiment 2

In Laudanna et al. (1989) we reported an inhibitory effect for inflected stem–homograph pairs like *mutarono* "they changed"/*mute* "mute (fem.pl.)" in a lexical decision task. The obtained effect was assumed to occur in a component of processing (the orthographic input lexicon), wherein these words are represented in morphologically decomposed form. In this component, when two morpheme homographs are presented sequentially, the entry for one (e.g., ⟨*mut-*, Adj, . . . ⟩ for *mute*) will be competitively inhibited by the previous activation of its homograph (the stem for *mutarono:* ⟨*mut-*, V, 1st Conj, . . . ⟩). It was further shown that this inhibitory effect cannot be attributed to either orthographic similarity or semantic relatedness, since it only occurs in the case of pseudomorphologically related pairs.

Based on this earlier work and its motivating assumptions, contrasting predictions can be made for the root and stem representation hypotheses with regard to the effect of root homographs. While both hypotheses hold that *mutarono* will activate the entry ⟨*mut-*, V, 1st Conj, . . . ⟩ in the input lexicon, the root representation hypothesis holds that this entry will also be activated by the derived form *mutevole* "changeable." The stem representation hypothesis, on the other hand, holds that the input lexicon entry for the derived form is ⟨*mutevol-*, . . . ⟩. Hence, on the root representation hypothesis, presentation of the prime *mutevole* should slow the recognition of *mute* due to the independently motivated inhibitory links between the root of the former (⟨*mut-*, V, 1st Conj, . . . ⟩) and that of the latter (⟨*mut-*, Adj, . . . ⟩). On the other hand, if the stem representation hypothesis is correct, the entry for *mutevole* in the input lexicon will not be identical to the root of that form, so the inhibitory effect should not be observed between *mutevole* and *mute*.

In Experiment 2 we compared the decision latencies on the same inflected target under priming conditions that exploit the contrasting predictions of the root and stem hypotheses. For example, reaction times and error rates were measured for *gradi* "degrees" preceded: by an inflected word containing the homographic root (*gradivate* "you liked"); by a derived word containing a homographic root (*gradimento*, the nominal "liking"); and by an unrelated control word (e.g., *nutrire* "to feed").

Method

Subjects

Forty-five subjects, all native speakers of Italian, completed the experiment. They each served for a single session and were paid for their participation.

Stimuli

Two hundred pairs of stimuli were presented to each subject in the course of the experimental session. The experimental stimuli were composed of 10 prime–target pairs for each of the three experimental conditions. In Condition I-I, inflected target words containing a homographic root were preceded by inflected primes whose root was the target's homographic mate. For example, *potete* "you (pl.) can" was preceded by *potarono* "they pruned," where the homographic stem was *pot-*. The inflected target words in the remaining conditions were the same as those in Condition I-I. In Condition D-I, the 10 inflected target words were preceded by a derived word containing the homographic root (in our example, *potete* preceded by *potatore*, "pruner"); and in Condition U-I, the 10 inflected target words were preceded by a word that was neither semantically nor orthographically related to the target (e.g., *potete* preceded by *espediente*, "device"). (The stimuli for this and the next experiment are provided in the Appendix.) The derivational suffixes for the primes in condition D-I are among the most productive and semantically transparent in Italian. They were the adjectival suffix *-evole*, which was presented in four of the primes, and the two nominalizing suffixes *-mento* and *-tore*, which were presented in the list of derived primes two and four times, respectively. The mean whole-word frequency of the 10 target stimuli was 25, and the mean root frequency was 183 (Bortolini et al., 1971). The target words consisted of six nouns and four verbs, and their mean length in letters was 5.6. The number of letters in common among the paired prime and target items for both categories I-I and D-I was 3.8.

Two additional measures can be computed for the prime–target pairs in order to assess the degree of orthographic similarity. These measures are both based on the proportion of letters in a stimulus that are shared (in the same serial position) with the item it is paired with. For example, in the stimulus pair *agio/agivate*, the shared letters are A, G and I. The first proportional measure of shared letters is based on the largest of the two items in the stimulus pair: AGI makes up 0.43 of the form *agivate*. We will refer to this as the minimal proportion of shared letters, because it provides the smaller of the two shared letter proportions when the prime and target stimuli differ in length in letters. The second measure of orthographic similarity is the mean of the proportion of shared letters in the prime and the proportion of shared letters in the target. To use the examples just given, the proportion of shared letters for *agio* is 0.75, and for *agivate*, 0.43; so the average proportion of shared letters will be 0.59. In Experiment 2, the minimal proportion of shared letters for the I-I and D-I stimuli was 0.54 and 0.45, respectively ($t = -1.79$, $df = 12$, $p = 0.098$). The average proportion

TABLE 2
EXPERIMENT 2

	Inflected root-homograph prime/inflected target (I-I) e.g., *potarono/potete*	Derived root-homograph prime/inflected target (D-I) e.g., *potatore/potete*	Unrelated prime/ inflected target (U-I) e.g., *espediente/potete*
RT	644	608	599
% errors	17.3	14.7	10.0

of shared letters for I-I and D-I pairs was 0.63 and 0.57, respectively ($t = -1.15$, $df = 16$, $p = 0.27$). These measures would suggest that any experimental differences observed for the two priming conditions would not be attributable to differences in the degree of orthographic similarity in the prime/target pairs.[3]

In order to ensure that subjects never saw any particular target item under more than one priming condition, the word pairs from the three experimental conditions were divided as in Experiment 1 into three sets. Each individual subject was presented with one-third of the stimuli (3 or 4 primes and an equivalent number of targets) from each experimental category, for a total of 10 pairs with no repeated words. All other list characteristics were the same as those in Experiment 1. In particular, it should be stressed that the 10 critical stimulus pairs were presented in the context of 190 filler pairs. Furthermore, of these 10 critical items, one-third of the subjects saw only six root homograph prime–target pairs (three I-I and three D-I pairs), while the other two-thirds of the subjects only saw seven such pairs (three I-I and four D-I pairs; or four I-I and three D-I pairs), with no repeated targets. Seven nonword targets in the list were preceded by an orthographically similar word or nonword prime—balancing the total number of I-I and D-I pairs that each subject saw. These manipulations were included in order to avoid any influence of task-specific strategy.

Materials and Equipment

These were the same as in Experiment 1.

Procedure

The experimental procedure was the same as in Experiment 1.

Results

Mean RTs and percentages of errors for the three experimental conditions are shown in Table 2. Target words preceded by inflected root homographs (Condition I-I) were responded to 45 ms slower than targets preceded by control words (Condition U-I), replicating the finding in Laudanna et al. (1989, Experiments 1–3). Target words preceded by inflected root homographs (Condition I-I) were also responded to 36 ms slower than target words preceded by derived root homographs (Condition D-I). The analysis of variance on reaction times revealed that the overall difference between experimental conditions was significant: Min $F(2,66) = 3.18$, $p < 0.05$ (by subjects, $F(2,42) = 5.02$, $p < 0.02$; by items, $F(2,27) = 8.60$, $p < 0.002$). Additional planned comparisons were in-

[3] There is one measure of orthographic relatedness on which the two conditions differ. On the basis of shared letters in the same serial position, the stimulus pair *fondarono/fondevano,* there are six shared letters (the initial letters, F, O, N, D, and the final letters N and O); but when only the initial adjacent letters of a prime–target pair are considered, there are only four letters common to the two stimuli (the initial F, O, N, D). Using this second notion of shared letters, the minimal proportion of shared letters is 0.40 for the D-I condition, and 0.52 for the I-I condition ($t = -2.25$, $df = 12$, $p = 0.044$). However, it is not at all clear that this measure is more (or even equally) appropriate in comparison to the measure based on the letters that are common in the same serial position. The average proportion of initial adjacent shared letters did not differ for the D-I and I-I conditions: 0.53 and 0.61, respectively ($t = -1.28$, $df = 17$, $p = 0.22$).

spected using Duncan's test (performed on the basis of subjects' variance): The test revealed that targets preceded by inflected stem homographs were significantly slower than those preceded either by derived stem homographs (I-I vs. D-I: $t(k = 2) = 4.20$, $p < 0.007$) or by controls (I-I vs. U-I: $t(k = 3) = 5.25$, $p < 0.002$), but there was no difference between targets primed by derived root homographs and those primed by controls (D-I vs. U-I: $t(k = 2) = 1.05$, n.s.). The analysis of variance on error data did not show reliable differences between categories either by subjects ($F(2,42) = 2.01$, $p > 0.10$) or by items ($F(2,27) = 1.21$, $p > 0.20$).

These results show that, while inflected root homographs inhibit their targets, the presentation of a derived prime does not induce any inhibition on the subsequent target. Bearing in mind our proposal that the inhibitory effect is based on the fact that one constituent of the addressed, morphologically decomposed lexical representation is orthographically identical in prime and target words, these results support the stem representation hypothesis. That is, in the case of inflected root homographs (e.g., *mutarono* and *mute*), the addressed entries—the roots ⟨*mut-*, V, 1st Conj., . . . ⟩ and ⟨*mut-*, Adj, . . . ⟩—have the same orthographic structure, which induces the activation of an inhibitory link between the two entries. This inhibitory link is posited to serve the requirement that the recognition device serving comprehension has as its goal the disambiguation of lexical input. Were the orthographic forms of the processing units distinct (as the surface forms of these items clearly are), this inhibitory link would not be motivated. On the account of lexical recognition that enlists morphological decomposition, though, the formal identity of the stems necessitates the disambiguating mechanism embodied in the inhibitory apparatus. In the case of the derived and inflected root homographs, though, the addressed decomposed entries are, respectively, the stem and root entries ⟨*mutevol-*, Adj, . . . ⟩ and ⟨*mut-*, Adj, . . . ⟩, which—not being orthographically identical—do not inhibit each other.

Experiment 3

As we have seen, the results from Experiment 2 corroborate the stem representation hypothesis for derived words. To verify that these results are not an artifact of the particular items selected, a third experiment was carried out. Basically, this experiment is a replication of Experiment 2 with an entirely new set of experimental stimuli.

Method

Subjects

Forty-five subjects participated in the experiment. They were all native speakers of Italian, students from the University of Rome, and they were paid for their participation.

Stimuli

In Experiment 3, the experimental stimuli were selected according to the same criteria as in Experiment 2. The inflected target words like *sparati* "shot (past participle)," whose stem is represented ⟨*spar-*, V, 1st Conj., . . . ⟩, were presented in three priming conditions: Condition I-I, preceded by an inflected word containing the homographic root/stem (e.g., *sparivano* "they disappeared," whose root/stem is ⟨*spar-*, V, 3rd Conj, . . . ⟩); Condition D-I, preceded by derived words containing the homographic root (e.g., *sparizione* "disappearance," whose root and stem are represented ⟨*spar-*, V, 3rd Conj, . . . ⟩ and ⟨*sparizion-*, N, fem, . . . ⟩, respectively); and Condition U-I, preceded by unrelated, control words (e.g., *versare* "to pour").

The number of stimuli in the experimental categories was also the same as in Experiments 1 and 2: Ten targets were repeated in the three priming conditions. Word pairs in each of the three experimental conditions were divided into three sets, and only one-third of the stimulus pairs (3 or 4 primes and an equivalent number of targets) was seen by any subject. Each subject was presented with a total of 10 pairs of words in which no target was repeated.

The frequency range of the targets was lower than in the other two experiments, but in that range we chose stimuli with the highest subjective frequency: mean whole-word frequency of the target stimuli was 8, mean root frequency was 22 (Bortolini et al., 1971). The target words consisted of seven nouns and three verbs, and their mean length in letters was 6.3. The number of letters in common among the paired prime and target items was 4.1 and 4.4 for categories I-I and D-I, respectively. The minimal proportion of shared letters for the I-I and D-I stimuli was 0.48 and 0.46, respectively ($t = -0.50$, $df = 15$, $p = 0.62$). The average proportion of shared letters for I-I and D-I pairs was 0.63 and 0.62, respectively ($t = -0.08$, $df = 17$, $p = 0.94$).

All derived root-homographs selected as primes for Condition D-I contained highly productive derivational suffixes. These included one occurrence each of the adjectival suffixes *-evole* and *-(a)bile* (both roughly corresponding to the English suffix *-able*), four occurrences of the nominalizing suffix *-zione* (English *-tion*), and one and three instances, respectively, of the nominalizing suffixes *-tore* and *-mento*. The other parameters of the list were the same as in Experiments 1 and 2.

Materials and Equipment

These were as in Experiments 1 and 2.

Procedure

The procedure in this experiment was the same as that in the preceding experiments.

Results

Mean reaction times and percentages of errors are shown in Table 3. The analysis of variance on reaction times by subjects ($F(2,42) = 7.60$, $p < 0.003$) by items ($F(2,27) = 4.47$, $p < 0.03$) confirmed the general difference between the three experimental categories found in Experiment 2. Min F on reaction times was marginally significant: Min $F(2,69) = 2.82$, $p < 0.07$. Error data did not give rise to significant differences either in the analysis by items ($F(2,27) = 0.90$) or in the analysis by subjects ($F(2,42) = 1.47$, $p > 0.20$). Furthermore, the pattern of results is very similar to that which emerged in Experiment 2. Responses for target words preceded by inflected stem homographs (Category I-I) were 28 ms slower than for those preceded by derived stem homographs (Condition D-I), and 38 ms slower than for those preceded by the unrelated control words (Condition U-I). Post hoc analyses for reaction times using Duncan's test, performed on the basis of subjects' variance, confirmed the results of the preceding experiment. The inflected prime condition differed significantly from the derived prime condition (I-I vs. D-I: $t(k = 2) = 3.70$, $p < 0.02$) and from the control condition (I-I vs. U-I: $t(k = 3) = 5.41$, $p < 0.001$), while there was no difference between the derived prime and the control conditions (D-I vs. U-I: $t(k = 2) = 1.71$, n.s.).

TABLE 3
EXPERIMENT 3

	Inflected root-homograph prime/inflected target (I-I) e.g., *sparivano/sparati*	Derived root-homograph prime/inflected target (D-I) e.g., *sparizione/sparati*	Unrelated prime/ inflected target (U-I) e.g., *versare/sparati*
RT	641	613	603
% errors	11.3	8.7	6.7

In summary, only (nonderived) inflected forms inhibit their root homographs. These results replicate those of Experiment 2 using an entirely different set of words, thereby providing further evidence in support of the stem representation hypothesis. Given that the results in Experiments 2 and 3 instantiate a null hypothesis (that there is no difference between D-I and U-I priming conditions), though, one might wish to subject the apparent failure of derived forms to prime words that are related by their roots to a somewhat more stringent test than we have previously considered. For example, it may be that an actual inhibitory effect is present, but that the effect is smaller than the one observed for I-I conditions and would therefore require more observations to become apparent. To test such a notion, we pooled the data from Experiments 2 and 3 in order to see if such a trend might emerge. The matching of conditions on frequency and grammatical category did not change. Nor did the pooled stimuli in the I-I and D-I conditions differ in measures of orthographic similarity: The minimal proportion of shared letters for the I-I and D-I stimuli was 0.51 and 0.45, respectively ($t = -1.76$, $df = 28$, $p = 0.09$). The average proportion of shared letters for I-I and D-I pairs was 0.62 and 0.59, respectively ($t = -0.93$, $df = 36$, $p = 0.36$). The results for the pooled analysis are given in Table 4.

The results remain consistent with those reported for Experiments 2 and 3 considered individually. The analysis of variance indicates that the overall difference in reaction times between experimental conditions is significant: Min $F(2,140) = 6.00$, $p < 0.005$ (by subjects, $F(2,87) = 12.1$, $p < 0.001$; by items, $F(2,57) = 11.9$, $p < 0.001$). We also calculated the power of the overall F test in the ANOVA for reaction time. Given the obtained variance in subjects' population for a number of subjects equal to 30 (as in the two pooled experiments) and setting the minimum difference of interest among means to 15 ms, the power of our test was found to be higher than .80—which is standardly accepted as the desired power value (Cohen, 1977, pp. 53–56); $f = .354$, $\Phi = .86$ for $\alpha = .05$. Comparisons using Duncan's test performed on the basis of subjects' variance revealed significant differences between condition I-I and the two other conditions (I-I vs. D-I: $t(k = 2) = 5.12$, $p < 0.001$; I-I vs. U-I: $t(k = 3) = 6.64$, $p < 0.001$), but not between conditions D-I and U-I ($t(k = 2) = 1.52$, n.s.). Analysis of variance for errors was significant by subjects ($F(2,87) = 3.4$, $p < 0.05$), but not by items ($F(2,57) = 2.1$, $p > 0.10$). A reliable difference was revealed by Duncan's test for the contrast between I-I and U-I ($t(k = 3) = 3.9$, $p < 0.01$); but not for the other comparisons (I-I vs. D-I: $t(k = 2) = 1.76$, n.s.: D-I vs. U-I: $t(k = 2) = 2.15$, n.s.). These analyses confirm the results obtained when the data from Experiments 2 and 3 were considered separately: Root homographs are inhibited by nonderived inflected forms, but not by derived forms.

Discussion

The results reported here allow two conclusions about the structure of lexical representation and processing. First, the reliable inhibitory effect found on inflectionally related forms with homographic roots—condition I-I in Experiments 2 and 3

TABLE 4
Experiments 2 & 3

	Inflected root-homograph prime/inflected target (I-I)	Derived root-homograph prime/inflected target (D-I)	Unrelated prime/ inflected target (U-I)
RT	643	610	601
% errors	14.3	11.7	8.3

and the experiments in Laudanna et al. (1989)—makes it necessary to posit a level of representation in which words are represented in terms of their morphemic constituents. This conclusion is motivated in part by the fact that the inhibition effect observed for stem homographs contrasted with a null effect of orthographic similarity and facilitatory effects for morphological and semantic relatedness (Laudanna et al., 1989).[4] This combination of results restricts the locus of the observed inhibition effect to a level of processing where strictly orthomorphological representations are computed. Second, the results presented here provide support for the representational distinction between inflectional and derivational morphology at the level of the orthographic input lexicon. The inflected form of a stem homograph (e.g., *spar-ivano*) inhibits an inflected stem (*spar-are*), but the derived form of a stem (e.g., *spar-izion-e*) does not. This finding indicates that there is a stage in lexical processing at which inflections, but not derivational affixes, are represented separately from their morphological bases (the stem representation hypothesis).

[4] Recent studies have reported that orthographically similar words can inhibit (Colombo, 1986; Segui & Grainger, 1990) or facilitate (Jordan, 1986; Segui & Grainger, 1990) each other. It is argued that these effects are highly dependent on the relative frequency of the prime and target (Colombo, 1986; Segui & Grainger, 1990); on the lexical status of the prime and on SOA (Colombo, 1986); and on the mode of presentation of the prime—i.e., masked vs. unmasked (Segui & Grainger, 1990). We will simply observe that these highly variable results contrast sharply with the robust and reliable inhibitory effects for stem homographs reported here and in Laudanna et al. (1989); and that, when orthographic similarity was examined directly in our studies (Laudana et al., 1989, Exp. 2), no inhibitory or facilitory effect emerged. More to the point of the present study, though, the comparable degree of orthographic similarity to the target in the derived and inflected priming conditions rules out any account of the observed asymmetric priming effects in terms of differences in orthographic relatedness.

This experimental evidence for the inflection–derivation distinction is not without precedent. For example, the spontaneous speech and single-word repetition performance of patient FS (Miceli & Caramazza, 1988) showed a selective impairment in producing inflections, while derivational morphology was left largely intact. This dissociation is clearly consistent with the view that the morphological form of a word represented in the lexicon is the inflectional base (see Tyler, Behrens, Cobb, & Marslen-Wilson, 1990, for a similar dissociation at the level of comprehension). Independent arguments for this division in the theory of morphology have also been proposed in linguistic analysis: See, for example, Aronoff (1976), Anderson (1982, 1988, forthcoming); and Di Sciullo and Williams (1987) for an opposing view.

However, there are also processing studies that appear to support the root representation hypothesis. In addition to the repetition priming studies mentioned in the Introduction, there are several studies of the effects of morpheme frequency that have been interpreted as support for the latter hypothesis. In one such study, Taft (1979) found that when words are matched on the frequency of the surface form but differ on the frequency of their morphological base, inflected and derivationally prefixed words with a high base frequency (e.g., *sized* and *reproach*) are recognized faster than inflected and derivationally prefixed words with a low base frequency (e.g., *ranked* and *dissuade*). Although the morpheme frequency effect for inflected forms has been successfully replicated (Burani, Salmaso, & Caramazza, 1984), Cole, Beauvillain, and Segui (1989) failed to replicate the root frequency effect for prefixed words. In a study with Italian subjects, Burani and Caramazza (1987) found that words matched on whole-word frequency with derivational suffixes were recognized faster if the frequency of the derivational base is high (e.g., *parlatore* "speaker") than if the derivational base frequency is low (*traditore* "betrayer"). The latter result has been replicated in a study with French subjects (Cole et al., 1989). Thus, it would appear that there is a reliable effect of morpheme frequency on lexical decision times for suffixed (though perhaps not prefixed) word forms. Since base frequency effects are taken as evidence that there is a level of analysis in the course of recognition at which the morphological base constitutes a representational unit, these results could be interpreted as evidence that lexical recognition includes some processing stage at which both inflected and derived words are morphologically decomposed (the root representation hypothesis). Hence, on this account—based on both the morpheme frequency and morpheme priming results—both derivational and inflectional affixes are represented separately from root morphemes.

How can we accommodate these discrepant results? As already noted in the introduction, the locus of the repetition priming effect is not obvious. If the notion of morphological decomposition is not limited to a single level of representation, though, the apparent difficulty might be easily resolved. For example, the orthographic units in the input lexicon most plausibly will not map in a one-to-one fashion onto representations at subsequent processing stages, even when these latter representations also reflect the morphological composition of a word. On both the stem and root representation hypotheses, for instance, *run* and its inflected forms *runs* and *running* will activate a common entry in the input lexicon (i.e., ⟨*run*, V, -trans., . . . ⟩). However, this does not preclude a separate entry for irregular forms like *ran*. If this distinction is made, though, it is presumably not made at levels where orthographic or phonological regularity are irrelevant. At a level where the *semantic* correlates of inflection are encoded there is no reason to believe that the representation for *ran* is any less compositional than any other past tense forms (or any other inflected forms of *run*). A similar distinction could also obtain for inflectional versus derivational morphology. On this account, one might explain morpheme priming and root frequency effects as taking place at a semantic processing stage (i.e., subsequent to lexical recognition), and not at the level of the orthographic (or phonological) input lexicon (Henderson, 1985).[5] Hence, while the priming and frequency phenomena may speak to issues of morphological representation, they do not make any transparent statements concerning the locus of effects. See Napps (1989) and Masson and Freeman (1990) for further discussion of facilitation effects deriving from repetition.

In the case of the inhibitory relation among stem homographs, though, it is difficult to imagine how the effect could reflect the organization of any level other than one at which lexical items are processed as (stem) forms—i.e., at the level of the input lexicon—since it is formal identify among stems that determine whether two representations will have an inhibitory link. Therefore, we may take the results reported here and in Laudanna et al. (1989) as support for the stem representation hypothesis concerning the entries of the orthographic input lexicon.

There remains one point that is worth pursuing and that is the question of why the inhibitory effect of stem homographs is found at all. Is there some purpose served by such links, or does the inhibition reflect characteristics of the system that are accidental with respect to its functional organization? While we cannot exclude accident out of hand, we can at least sketch a func-

[5] Frequency exerts an influence over a wide range of lexical tasks (lexical decision, naming, semantic categorization, and syntactic categorization—see Monsell, Doyle, and Haggard 1989). This also raises the possibility that phenomena such as the stem frequency effects reflect facilitation at multiple processing levels.

tional motivation as an alternative. Our reasoning follows from the observation that the goal of a form-based access system is to narrow to one the set of lexical forms that are initially considered as candidates for match with a written word. At one extreme, an item with few orthographic neighbors can, in principle, be identified simply with reference to the overt form of the stimulus. At the other extreme, homographic forms will either be distinguished by contextual factors or, where this fails, by such factors as the familiarity-based dominance of one meaning over the other (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982). Regardless of the method of "disambiguation," though, the formal identity of homographs puts such items in a competition that, by definition, cannot be resolved by the degree of orthographic correspondence to the stimulus. In such circumstances, the goal of access favors a mechanism of competitive inhibition, since this is nothing more than a means internal to the lexical system for dealing with the problem of ambiguity resolution (Caramazza et al., 1988). The details of competitive inhibition remain underspecified. Nevertheless, the results reported here and in Laudanna et al. (1989) have provided important information concerning the types of representational units that are linked in this manner. In particular, these studies indicate that it is the inflectional stem (as opposed to whole word or derivational root) that is listed in the orthographic input lexicon and subject to inhibitory effects from homographic forms.

APPENDIX

Stimuli from Experiment 2

Condition D-I

Prime	Target
agevole	agivate
colpitore	colpa
colpevole	colpo
durevole	dure
fondatore	fondevano
gradevole	gradi
portamento	porte
rapimento	rapa
potatore	potete
volatori	volevano

Condition I-I

Prime	Target
agio	agivate
colpire	colpa
colpa	colpo
durava	dure
fondarono	fondevano
gradito	gradi
portavano	porte
rapire	rapa
potarono	potete
volate	volevano

Condition U-I

Prime	Target
limpido	agivate
metri	colpa
lampone	colpo
nutrire	dure
oppongo	fondevano
negligenza	gradi
piccolo	porte
giovane	rapa
espediente	potete
pioveva	volevano

Stimuli from Experiment 3

Condition D-I

Prime	Target
mutevole	mute
fornitore	forni
sparizione	sparati
consolazione	console
ardimento	ardete
finimento	fina
violazione	viole
ballabile	balle
gradazione	graditi
paramento	parevano

Condition I-I

Prime	Target
mutarono	mute
fornirete	forni
sparivano	sparati
consolate	console
ardirete	ardete
finivano	fina
violarono	viole
balleranno	balle
grado	graditi
parate	parevano

Condition U-I

Prime	Target
ammirare	mute
tollerare	forni
versare	sparati
esaurimento	console
sospetta	ardete
ambizione	fina
tormentare	viole
preventivo	balle
immersione	graditi
desiderare	parevano

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