Priming Homographic Stems

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Three lexical decision experiments were carried out to address the issue of the morphological organization of lexical representations in the orthographic (input) lexicon. Lexical decisions were more difficult for simultaneously or sequentially presented words with homographic stems than for control words that did not have homographic stems. Stem homographs are stems that are orthographically identical but semantically and/or grammatically different. Lexical decisions for stimulus pairs such as portare (to carry)/porte (doors), which share the stem port-, were difficult relative to nonhomographic stem pairs such as collo (neck)/colpo (blow), which have the stems coll- and colp-. It was also found that morphologically related forms of the same ambiguous stem (e.g., porta (door)/porte (doors)) are easiest to process. The pattern of results provides strong support for the hypothesis that lexical representations are stored in morphologically decomposed form.

One of the central issues in the study of language processing concerns the types of representations and mechanisms involved in the course of recognizing lexical forms and accessing corresponding entries in the mental lexicon. In this regard, a number of recent studies in psycholinguistics and the cognitive neuropsychology of language have emphasized the crucial role played by the morphemic structure of written words. (See Taft, 1985; Badecker & Caramazza, 1988, for reviews.) Evidence from these studies has led to the development of a variety of models in which morphological principles (partially) determine the lexical access procedures and/or the content and organization of lexical entries. Apart from those who differ among themselves concerning the details of morphology's influence in lexical processing, there also remain some who deny that morphology has any role at all in normal processing. The experiments described in this paper were carried out in order to address this dispute, but also to test specific predictions concerning the morphological decomposition hypothesis.

Some of the most robust effects of morphological structure have been found in experiments employing nonwords with varying degrees of decomposability. In lexical decision tasks, for example, reaction times and/or error rates are significantly affected by morphological complexity: Subjects are slower and produce more errors when rejecting nonwords that can be parsed into actual stem and suffixes (e.g., walkest) than when rejecting nonwords that only contain...
a pseudostem (walkost) or a pseudosuffix (wilkest), and they perform better still on nonwords (like wilkest) that contain no morpheme-like sequences at all (Taft & Forster, 1975, 1976; Henderson, Wallis, & Knight, 1984; Caramazza, Laudanna, & Romani, 1988). Furthermore, within the class of nonwords that are fully decomposable into morphemic components, performance is also affected by the types of grammatical relationships that exist between the morphemes that comprise a stimulus item. For example, Caramazza et al. (1988) found longer reaction times for rejecting Italian nonwords in which normally suppleted stems are combined with conjugation appropriate suffixes than for stems combined with suffixes from another conjugation.

Parallel results from the analysis of acquired language disorders have also been reported. For example, patient LB (Caramazza, Miceli, Silveri, & Laudanna, 1985) presented with a striking dissociation between an impaired ability to read nonwords and an intact ability to read words. LB’s success in nonword reading was strongly determined by the degree of morphological structure: He was able to read fully decomposable nonwords better than nonwords that contain only a stem or affix sequence, and his performance was worst on nonwords with no morphemic sequences at all.

Evidence for morphological decomposition during lexical access also derives from two sorts of word-based paradigms. The first of these concerns the effect of stimulus frequency. A standard assumption regarding the well-documented effect of frequency in lexical decision tasks is that it derives from the familiarity of units of processing that comprise the stimulus. Several studies have shown that for morphologically complex words, the response to a target word is a function not only of the frequency of the entire word (surface frequency), but also of the summed frequency of the affixed forms of the word’s stem (stem frequency). For example, the influence of stem frequency has been found for inflected words, productive derived words, and compounds (Taft, 1979; Burani, Salmaso, & Caramazza, 1984; Burani & Caramazza, 1987; Andrews, 1986).

Priming effects have been taken to provide a second form of word-based evidence for the role of morphological structure in lexical processing. Repetition (or identity) priming is commonly construed as the result of the facilitating effect on the access procedure of the repeated activation of the lexical representation of a target word. A number of studies have demonstrated that priming a lexical item with a morphologically related word (stem priming) may be as effective as identity priming (e.g., Stanthers, Neiser, Hernon, & Hall, 1979; Fowler, Napps, & Feldman, 1985; Kempley & Morton, 1982). Under the assumptions of the repeated activation hypothesis, stem priming is consistent with the notion that the units of activation include the morphemic subcomponents of a word.

Finally, independent evidence in favor of the morphological decomposition of lexical entries has been obtained from subjects with acquired language impairments. The patterns of errors in patient FS’s spontaneous speech and repetition performance indicates that the processing and/or representation of inflectional morphology is independent from that of lexical stems and derivational morphology (Miceli & Caramazza, 1988), while the acquired dysgraphia of patient DH strongly supports the hypothesis that words are processed in units corresponding to the productive morphemes of the language (Badecker, Hillis, & Caramazza, 1988). Several case studies of acquired dyslexia that is characterized (in part) by the production of morphological paralexias have also been taken as support for morphological decomposition (Coltheart, 1984; Job & Sartori, 1984; Patterson, 1982).

In order to make these results more concrete, we will briefly discuss one model of lexical processing formulated to account for the various findings concerning morphologically complex words: the augmented addressed morphology (AAM)
model (Caramazza et al., 1985, 1988; Laudanna & Burani, 1985). (For a discussion of other lexical processing models that hypothesize morphological decomposition during access, the reader is referred to Taft, 1985, and Caramazza et al., 1988.) A distinguishing feature of the AAM model is its assumption that lexical access to morphologically complex words may take place through a whole-word address procedure, for known words, or through a morpheme address procedure, for novel words. The access mechanism in the AAM model is characterized as a parallel activation system where the degree of activation of a stored orthographic representation is a function of the graphemic similarity between an input letter string and the stored representation (Morton, 1969). Both whole-word and morpheme access mechanisms address morphologically decomposed entries in the orthographic input lexicon. There are three assumptions concerning these mechanisms that are of interest here.

The first is that, for known words, a letter string simultaneously activates both a whole-word representation and representations corresponding to the morphemes that comprise the word. The second is that the activation of a whole-word representation is faster in accessing a lexical entry than is the activation of the morphemic constituents of the word. The third assumption concerns the computational primitiveness of the procedures that access entries in the input lexicon. The access procedures are sensitive only to the superficial aspects of word structure (e.g., whether a stimulus matches a whole-word representation and/or whether it can be exhaustively parsed into morphemic units). Lexical/grammatical information about actual or potential words is represented at the level of the orthographic input lexicon. It is the latter component which will include information about the combinatory properties of constituent morphemes (see Caramazza et al., 1988, for detailed discussion).

It should be evident that the experimental results discussed above conform well to the expectations derived from the hypothesized access procedures and representational format for lexical items in the AAM model. The effect of morphological structure on nonword processing follows from the fact that fully parsable nonwords (like *walkest*) may be rejected only after evaluating the combinability of the addressed morphemes that comprise it, while a corresponding nondecomposable stimulus (e.g., *wilkost*) may be rejected prior to this processing stage because neither stem nor affix nor (of course) whole-word address procedures are activated. The effects of surface and stem frequency found for morphologically complex words derive from the fact that frequency sensitivity is a property of both the address procedures (and, possibly, the representations of the input lexicon). Stem frequency effects for morphologically complex words reflect the characteristics of their decomposed representations in the orthographic input lexicon. Surface frequency effects, on the other hand, reveal the properties of the whole-word address procedures that access the entries in the input lexicon. Finally, the AAM model provides the representational types necessary to sustain the account of stem priming that is based on the repeated activation of lexical entries. Stem priming is the direct consequence of accessing the shared morpheme entry in the input lexicon for both members of a morphologically related pair of words.

While the results we have reviewed are relatively well known, the interpretation that we have offered for them remains somewhat controversial, even apart from the details of the AAM model of lexical processing. Results which we argue point to the decomposition of complex words have been criticized on a variety of grounds. For example, one criticism concerns the type of stimuli that may be used to study lexical processing. Henderson (1985) disparaged the use of nonword stimuli when the goal of the research is to illuminate the mechanisms and representations involved in the recognition of familiar words. This objec-
tion appears to be based on what we take to be an unreasonable assumption: That the mechanisms for accessing the stored representations corresponding to familiar and novel words and those which are available for processing nonwords are disjoint. (See Caramazza et al., 1988, for discussion). Nevertheless, the contrary position suggests that there should be some experimental paradigm in which evidence for decompositional access procedures could be found with word stimuli. Thus, it is somewhat unfortunate that the strongest criticisms of the proposed evidence for decomposition are leveled against the stem frequency and stem priming experiments. Generally speaking, these complaints focus on the possibility that some experimental results could reflect the involvement of sources of information different from the morphological properties of words. It is argued that, even if they are clearly compatible with a morphologically organized model of lexical representation and access, they cannot be transparently interpreted as support for the hypothesized morphological decomposition. For example, the stem frequency effect has been viewed as compatible also with the hypothesis of single lexical entries for morphologically complex words (Butterworth, 1983; see also Henderson, 1985). On such an account, the effect might derive from the clustering of all transparently related words under the same tag or "name." If this tag is activated every time a word listed under it is accessed, it is argued, then the stem frequency effect might simply be the product of differences in the accessibility of these tags (or keys) to the subordinate clusters of morphologically related words (Butterworth, 1983). The lexical nature of repeated-morpheme priming has also been questioned: Accounts of priming have attributed the effect to cognitive mechanisms other than those devoted to word or morpheme access, including episodic memory traces, response-learning, and "contextual" influences (see Monsell, 1985, for a review). Similar criticisms have been raised against particular uses of patient data (Job & Sartori, 1984; Patterson, 1982) as evidence for morphological decomposition in the course of lexical access. For putative morphological errors it is often possible to formulate an account in terms of visual or semantic relatedness of a response word to its target (Badecker & Caramazza, 1987; Funnell, 1987).

In summary, if one goal of research on morphological processing and representation is to have unambiguous criteria for interpreting word processing data, then the core of the problem seems to reside in the isolation of a "purely" morphological condition—i.e., a condition, for visual word processing, in which morphological information may be contrasted with both orthographic and semantic information. In the three experiments presented here, our purpose was to evaluate and extend the hypothesis of morphological decomposition by creating experimental conditions that would elicit inhibitory effects selectively based on the morphological structure of lexical items. This was achieved by introducing contrasting information about the combinability of the morphemes that comprise a word in a lexical decision context.

**Experiment 1**

To evaluate the plausibility of the claim that lexical representations are morphologically decomposed, it is first necessary to specify two aspects of our hypothesis with regard to lexical decision. The first of these concerns the type of information needed to determine the legality of particular morpheme combinations. The second relates to the process by which lexicality decisions can be made.

In order to determine whether a particular stem + affix combination forms a word of the language, one must invoke information about both stem and affix types. In particular, we suggest that each regular stem is marked for a number of grammatical features that, among other things, are sufficient to specify which affix it will accept for
any specific combination of inflectional features (e.g., person, number, gender, verbal tense, etc.). The examples that are pertinent to the present experiments are from the inflectional system of Italian. For instance, verbal inflections in Italian are distinguished in terms of conjugational type, so features which encode grammatical category and conjugation are needed to determine the set of inflectional affixes that may be accepted by a particular stem. Similarly, verbal suffixes will be marked for particular conjugations, in addition to the grammatical distinctions that they encode. The same situation will obtain in the case of nouns, where the set of inflectional markers must be selected on the basis of the gender specification of the stem, and with adjectives, where endings must be of the type that distinguish gender and number or of the type that distinguish number only. For concreteness, consider the case of the nominals casa (house) and albero (tree). The stem cas- bears the grammatical features [+ noun, + feminine], which will select the singular and plural suffixes -a and -e; while alber- is specified [+ noun, + masculine], selecting the inflections -o and -i. Thus, we can postulate the following entries in the input lexicon: (cas-, N, Fem, a/e); (alber-, N, Masc, o/i); (-a, N)——, Fem SG); (-o, N)——, Masc, SG); (-i, N)——, PL); etc. This representational structure (by which stems and affixes are marked for relevant grammatical features) generates all the legal stem + suffix combinations and allows the productive recognition of novel, regularly inflected forms.

As to the decision process about lexicality, we follow the assumption (Caramazza et al., 1988) that the access units which reach threshold will address their corresponding representations in the input lexicon and that, if the addressed morphemes represented there constitute a legal combination, then a positive response is initiated. Otherwise, the stimulus is taken to be a nonword. In order to articulate our hypothesis about the experimental effect to be described below, it is necessary to give a more specific characterization of the lexicality decision process for a particular type of word—that which contains an orthographically ambiguous stem.

We have hypothesized that lexical entries are represented in the orthographic input lexicon in morphologically decomposed form, and that each stem is marked with the grammatical features which serve to specify the set of morphemes with which it will combine. Given these two assumptions, we may then ask what will happen when an orthographically ambiguous stem is activated in the lexicon. Consider, for example, the verb portare (to carry), whose stem is represented in the lexicon as (port-, V, 1st Conj). This stem is ambiguous because it is identical to the stem for the noun porte (doors), whose entry is (port-, N, Fem, a/e). (Henceforth we will refer to these as homographic stems.) The verbal stem port- is linked to the set of inflectional verbal affixes of the first conjugation: (-are, V)——, 1st Conj, Infinitive), (-o, V)——, 1st Conj, Present, 1st Person, SG), etc. This stem will have inhibitory links (or will have no links) to the sets of affixes for the other verbal conjugations, or with adjective and noun endings. The same schema applies for the homographic stem for the noun porte (doors). In this case, the grammatical features of the stem entry will link it to the set of compatible nominal suffixes: -a (SG) and -e (PL). It also will have inhibitory links (or no links) to the set of affixes for masculine nouns, verbs, adjectives, etc. Under normal access conditions there should be no observable difference between these stems and unambiguous stems. Their grammatical features allow the activation of the link with the appropriate set of admissible affixes.

The situation is not quite as simple when the entries corresponding to both portare and porte are activated (by their respective whole-word address procedures). Under these circumstances, the effects of inhibitory links between the homographic stems or the stems and the inappropriate sets of
affixes might be observed. In our experiments we tested these predictions of the AAM model by comparing subjects' performance on a double-word lexical decision task for word pairs with homographic stems \(\text{portare, porte}\) and word pairs that have only visually similar stems \(\text{contare (to count), corta (short)}.\) The prediction of the AAM model is that lexical decision performance for homographic stem pairs should be worse in comparison to control pairs of stimuli. When the access units corresponding to two visually similar words with distinct stems address their morphologically decomposed lexical representations ((cow, V, l%onj) + (-are, . . .) and (tort-, Adj, . . .) + (-a, Adj|]-, . . .) in our example), the activated representations in the input lexicon will license positive responses. For the stimulus pairs containing homographic stems, we assume that, since the systems output must be limited to a single response, the first lexical (stem) representation to be activated will (partially) inhibit the activation of the other, making the double-word decision more difficult for these stimuli. That is, if the access representation of \(\text{portare (port-, V, l%onj)} + (-are, . . .)\) were to reach threshold first, the activation of \(\text{port, V, . . .}\) would partially inhibit the activation of the stem representation \(\text{(port-, N, Fem, a/e).}\) Thus, the decision for the combination \(\text{(port-, N, . . .) + (-e, N|]-, . . .}\) would emerge only after the resultant conflict is subsequently reconciled. This negative interaction should render the decision for homographic stem pairs relatively more difficult than those for control stimuli. Alternatively, we could assume that the activation of the homographic stems is mutually inhibitory. In either case, though, the effect should be worse performance for homographic stem pairs than for controls.

**Method**

**Stimuli**

The experimental list was composed of 300 pairs of stimuli that were presented to each subject in a single experimental session. The stimuli were 150 word–word pairs, 75 nonword–word pairs, and 75 nonword–nonword pairs. Of the 150 word–word pairs, 15 were homographic stem word pairs (e.g., \(\text{portare, porte}\)) and 15 were orthographically similar word pairs (e.g., \(\text{contare, corta}\)). These two classes of stimuli were matched for length (mean length was 5.7 letters in both experimental conditions), stem frequency (mean stem frequency was 75 for the homographic stem pairs and 72 for the control word pairs (Bortolini et al., 1971)), surface frequency (25 for both categories), form class (there were 16 nouns, 12 verbs, and 2 adjectives in each category), and the number of letters in common among the two elements in the pair (on average, 4 1 letters in common out of 5.7 in both experimental conditions). No stem appeared in the list more than once. The distribution of suffix types was similar across the two categories. To be certain that the mere presence of an ambiguous stem did not contribute significantly to any effect that might be found, the stems in the orthographically similar word pairs were limited to ambiguous stems. (In our example, \(\text{cont-}\) is orthographically identical to the stem of the noun conte (earl) and \(\text{tort-}\) is orthographically identical to the stem of the noun corte (court).)

As a control of the adequacy of the experimental list in the case of a null result on these two experimental categories, two more experimental categories were included in the list, each formed by 15 double-word pairs. They were not directly matched with the earlier two categories and consisted of one set of semantically associated items and one matched set of unrelated items. (The effect of semantic priming in a double lexical decision task was ascertained by Meyer & Schvaneveldt, 1971). The 30 word stimuli in each of these experimental conditions were singular nouns whose mean length was 5.5 letters. The root and surface frequencies were, respectively, 71 and 36 for the semantically asso-
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There were 225 nonwords (75 in word-nonword pairs, and 150 in nonword-word pairs). The nonwords were obtained by changing one or two letters from an actual Italian word. The letters were changed 75 times each in the initial, medial, and final third of the base word, and always according to the orthotactic constraints of the language. Given that, in Italian, orthographically legal "words" must end with a vowel (A, E, I, or O) and that these four vowels are all possible nominal, adjectival, or verbal suffixes, it follows that the nonwords were "suffixed" (like all orthographically legal Italian nonwords). In addition, the list contained 45 nonwords (20%) containing an unambiguous verbal suffix of two letters or more (e.g., deit-ato, scil-ava) and 30 nonwords (13%) that contained unambiguous adjectival or nominal suffixes (e.g., on-atore, cast-ale).

The 225 base words for the nonwords were matched by item in length, form class, and approximate frequency with 225 words randomly selected from the corpus of 375 experimental and filler words in the list (120 experimental words and 180 filler words from word-word pairs, and 75 filler words from word-nonword pairs). Thus, the resulting nonwords were drawn from base words comprised of 74 verbs (33%), 120 nouns (53%), and 31 adjectives (14%). (These proportions closely reflect the form class distribution of the whole list of stimulus words: 114 verbs (30%), 208 nouns (55%), and 53 adjectives (14%).

Materials and Equipment

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

Procedure

In the first experiment, a double lexical decision task was employed in which subjects were required to recognize both items as a word or a nonword. Subjects were instructed to be as fast and as accurate as possible. They responded by pushing one button when they recognized both of the stimuli as words and another when they considered at least one of the stimuli to be a nonword.

The experimental sequence began with a brief tone, which was followed after 600 ms with the presentation of a fixation point in the center of the screen. After 400 ms the fixation point was replaced by the two letter strings that comprise the stimulus pair: The strings were displayed simultaneously on the screen, one centered immediately above the fixation point and the other centered immediately below the fixation point. If a subject did not respond before a preset limit of 1500 ms, the two items disappeared and the words "piu' veloce" (quicker) appeared on the screen. If the subjects gave the wrong response, the word "errore" (error) appeared on the screen. When subjects gave the right response, the reaction time (in milliseconds) appeared on the screen after the disappearance of the stimulus. Response time feedback (or error signal) was shown on the screen for 1000 ms. The intertrial interval between the disappearance of the feedback information and the start of the next warning signal was fixed and lasted 1000 ms.

Reaction times were measured from the onset of a stimulus to the time when a subject pressed the response button. The total pool of 300 stimuli, arranged in three different random orders, was presented to all the subjects, after two blocks of 25 practice trials each. The stimuli were organized into four blocks of 75 item pairs. No experimental word pair was included among the first four pairs of a block. There was a one minute rest period between blocks.

Subjects

Twenty subjects, all native speakers of Italian, completed the experiment. They served for one session lasting about 40 min and they were paid for their participation in the experiment.
Results

Mean reaction times and percentage of errors are shown in Table 1. Analyses of variance, by subjects and by items, performed on reaction times (RT) and error data revealed significant differences among stimulus conditions. For RT, $MinF(3,132) = 10.9, p < 0.001$; for errors, $MinF(3,121) = 5.03, p < 0.005$. Additional planned comparisons were carried out in order to detail the pattern of reliable differences among stimulus types. The critical result concerns the performance measures for the stem homograph pairs and the orthographically similar pairs. In accord with our predictions, the stem homograph pairs were 42 ms slower than their orthographically similar counterparts, and they induced more errors than the orthographic pairs. One way Anovas revealed a significant difference for reaction times (by items: $F(1,28) = 5.15, p < 0.05$; by subjects: $F(1,38) = 7.02, p < 0.02$), although the $MinF$ comparison was only marginally significant ($MinF(1,61) = 2.97, p = 0.09$). Error rates differed on each measure (by items: $F(1,28) = 6.90, p < 0.02$; by subjects: $F(1,38) = 9.94, p < 0.005$; $MinF(1,61) = 4.08, p < 0.05$). In the case of the semantically related versus unrelated items, responses for semantically related pairs were 86 ms faster than for control pairs ($MinF(1,66) = 15.90, p < 0.001$), but the difference in error rate was not significant.

The results of the first experiment show that response latencies are higher on pairs of words containing homographic stems than on pairs of words with orthographically similar stems, indicating that the processing of the former pairs of words is not simply affected by the orthographic similarity among the stimuli. The main conclusion we can draw from these results is that the difference between performance on homographic stem words and orthographically similar words is due to the interaction between representations in a processing component organized along morphological dimensions—presumably at the level of the orthographic input lexicon. By the same token, these results are incompatible with the view that the representations that are activated in the input lexicon correspond to whole-word units. The impeded performance on stem homograph pairs can be explained only if we assume that lexical representations are morphologically decomposed and that the representation corresponding to one of the two ambiguous stems is inhibited (or, alternatively, that they are both inhibited) in the course of access. Furthermore, we may assume that the (presumably inhibitory) effect on homographic stem results from the organization of the orthographic input lexicon proposed in the context of the AAM model. In this component, and in the context of a task in which pairs of stem homographs are processed together, a competitive process is initiated in which facilitory and inhibitory activations summate to determine whether a particular stem + suffix combination will be accepted as a word, and this processing has the effect of increasing the difficulty of lexical decision.

Experiment 2

The results of the first experiment showed that the effect of inhibition for homographic stem pairs is not based solely on the orthographic structure of the stimuli. However, those results do not allow us to conclude that orthographic similarity was not responsible at all for the slower reaction times on the homographic stem pairs.
Therefore, the first objective of our second experiment was to ascertain whether the mere orthographic similarity between the stimuli in the pairs contributed to the inhibitory effect. This issue was approached by directly comparing in the same task both the orthographically similar word pairs and the stem homograph pairs with a control condition represented by unrelated word pairs.

The second objective of this experiment was to investigate a different aspect of the morphological organization of the orthographic input lexicon through the examination of word pairs in which both items constitute regularly inflected forms of the same, orthographically ambiguous stem (e.g., voltare "to turn" and voltavo "I was turning"). If our explanation of the results in Experiment 1 were correct, then it would follow that, when morphologically related word pairs containing the same ambiguous stem are encountered and their morphemic components are accessed in the lexicon ((volt-, V, 1\textsuperscript{st}Conj) + (-are, . . .) and (volt-, V, 1\textsuperscript{st}Conj) + (-avo, . . .) in our example), then the inhibitory effect observed in the processing of the stem homograph pairs should not arise. On the contrary, the hypothesized organization of the orthographic input lexicon suggests that, in the case of words that constitute possible inflections of the same stem, the repeated access of the same entry should facilitate the process of lexical decision.

In order to investigate these two issues, the experimental stimuli in the second experiment were matched across the following four categories: (a) homographic stem word pairs, (b) orthographically similar word pairs, (c) morphologically related word pairs, and (d) unrelated word pairs. For this experiment we formulated three predictions. The first was simply that we would replicate the finding for stem homograph pairs (this time in comparison with the other three experimental categories). This expectation derives from the same model explicated in the introduction of Experiment 1. Second, we predicted a facilitory effect (faster reaction times and errors than on the other three types of experimental stimuli) for the morphologically related items. In our example, the lexical stimulus voltare will bring about the activation of the stem (volt-, V, 1\textsuperscript{st}Conj, . . .), which in turn will facilitate the decision for the second word, voltavo. Finally, we hypothesized that the contribution of orthographic similarity to the morphological effects in this task was not reliable; we predicted that, if found, any effect for orthographic similarity would be independent from the morphologically based ones. This prediction could have two empirical consequences for the category of orthographically similar word pairs: Either they would not differ significantly from control stimuli; or they would differ from control stimuli, but they would also differ significantly from both the stem homograph pairs and the morphologically related pairs.

**Method**

**Stimuli**

Three hundred pairs of words were presented to each subject in a single experimental session. The experimental stimuli were composed of 15 word pairs for each of the four experimental conditions included in the experiment: Cat.1: stem homograph pairs (e.g., portare, porte); Cat.2: orthographically similar (e.g., contare, corta); Cat.3: morphologically related (e.g., posto "place," posti "places"); and Cat.4: unrelated (e.g., causa "cause," ponte "bridge"). New stimulus items were created for all categories using exactly the same criteria as in Experiment 1. Mean length was identical across the four experimental conditions (5.8 letters). Root and surface frequencies (Bortolini et al., 1971) had the following values in the four experimental categories: Cat.1: 60 and 13; Cat.2: 62 and 12; Cat.3: 59 and 12; and Cat.4: 62 and 13. The form class of the 30 experimental words was roughly balanced in the four categories: Cat.1: 16 nouns, 11
verbs, 3 adjectives; Cat.2: 18 nouns, 10 verbs, 2 adjectives; Cat.3: 15 nouns, 11 verbs, 4 adjectives; Cat.4: 16 nouns, 12 verbs, 2 adjectives.

The first three categories of morphologically and/or orthographically related words (Cat.1, Cat.2, and Cat.3) were controlled for two other aspects: The two words in the stimulus pair had the identical number of letters in common (on average, 4.3 out of 5.8); and all the stems used in the three categories were ambiguous. (In the new example given for morphologically related words, the two words posto and posti have the stem \(\text{post-}, \ N, \text{Masc, o/i}\), which is homographic with the stem \(\text{post-}, \ N, \text{Fem, a/e}\) of the word posta "mail.") No stem appeared in the list more than once.

To avoid the overrepresentation of orthographically and/or similar word pairs in the list, each individual subject saw only one half (7 or 8) of the stimuli in each category for a total of 30 stimuli out of 300. Two subjects presented with the two complementary parts of the experimental categories formed a "supersubject"—that is, represented a single point for statistical analysis. Each individual subject was also tested on 120 word–word pairs, 75 word–nonword pairs, and 75 nonword pairs, for a total of 150 Yes responses and 150 No responses.

The procedure adopted to construct nonwords was the same as in Experiment 1. The nonwords were derived from a set of base words comprised of 76 verbs, 114 nouns, and 35 adjectives, reflecting the distribution (by length and form class) of the 435 words in the stimulus list. All of the nonwords ended in a legal suffix; 45 contained an unambiguous (multiletter) verbal inflection, while 30 ended with a derivational affix.

Materials and Equipment

These were as in Experiment 1.

Procedure

The procedure was the same as in the first experiment. The only difference was that in this experiment the stimuli were organized and presented to the subjects into five blocks of 60 item pairs.

Subjects

Forty subjects completed the experiment, for a total of 20 supersubjects. They were paid for their participation in the experiment.

Results

Mean reaction times and percentages of errors are shown in Table 2. An analysis of variance, by item and by subjects, showed a strong effect of experimental conditions for reaction times: MinF(3,138) = 3.22, \(p < 0.025\). The effect of stimulus type for error data was obtained in the analysis by subjects (\(F(3,76) = 5.67, p < 0.01\), but it is far from significant in the analysis by items (\(F(3,56) = 1.02, p = 0.39\)). Given that the effect on errors is not reliable, we will only consider reaction time data in our discussion. Further comparisons between pairs of experimental categories were carried out with Duncan’s test in order to evaluate our three hypotheses more precisely.

The first hypothesis formulated with regard to this experiment concerned the performance on stem homograph pairs as compared to the three other experimental categories. The results of this comparison revealed significant differences from all other stimulus types: For Cat.1 versus Cat.2, stem homograph pairs were 42 ms slower than orthographically related pairs (\(t(k = 3) = 3.52, p < 0.05\)). For Cat.1 versus Cat.3, stem homographs were 74 ms slower than the morphologically related pairs (\(t(k = 4) = 6.24, p < 0.001\)). For

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<thead>
<tr>
<th>Stimulus categories</th>
<th>Stem homographs</th>
<th>Orth. similar</th>
<th>Morph. related</th>
<th>Unrelated</th>
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Cat.1 versus Cat.4, stem homographs were 38 ms slower than the unrelated controls ($t(k = 2) = 3.20, p < 0.05$).

The second hypothesis was relative to the facilitation for morphologically related word pairs; and the comparisons relevant to test this hypothesis showed that the morphologically related stimulus pairs (Cat.3) were responded to 32 ms faster than the orthographically similar (Cat.2) and 36 ms faster than the unrelated (Cat.4) stimuli: $t(k = 2) = 2.72, p < 0.05$ and $t(k = 3) = 3.05, p < 0.05$, respectively.

Finally, we hypothesized no contribution (or no reliable contribution) of orthographic similarity to the morphological effects of inhibition (on stem homographs) and facilitation (for the stem-sharing pairs). We have seen that the stimuli in Cat.2 (orthographically similar word pairs) were responded to significantly faster than stem homograph word pairs and significantly slower than word pairs with the same stem. Furthermore, no difference was found between orthographically similar and unrelated pairs (Cat.2 and Cat.4, respectively): $t(k = 2) = 0.34$. These results allow us to reject the hypothesis that the effect of inhibition on homographic stem pairs (or the effect of facilitation on morphologically related items) is due to the orthographic similarity between the two words in the pair. Instead, the internal variation of the results seems completely explainable in terms of the experimental manipulations of the morphological relationships among the word stimuli in the pairs.

**Experiment 3**

In our explanation of the results of the two experiments we have reported, we assumed that in the processing of the stem homograph pairs, the lexical representation that is activated first partially inhibits the activation of its homographic mate. The activation of this inhibitory link would explain the slower reaction times on these stimuli. What cannot be addressed by the data presented so far is whether the inhibitory effect is symmetric. For example, in the two experiments reported above, one of the factors which could be responsible for a more rapid activation of one representation versus the other in the pair is the relative frequency of the two words. The representation corresponding to the more frequent word could be activated first, inhibiting the activation of the less frequent mate. This account leaves open the possibility that, while the more frequent item might inhibit its less frequent cohort, the low frequency stem homograph cannot inhibit its more frequent partner.

In the third experiment we chose to investigate this aspect of the hypothesized mechanisms more directly. For this purpose we slightly changed the experimental situation in such a way as to force the subjects to process one stimulus before the other. Instead of presenting the two stimuli simultaneously, we chose to present the items from each pair sequentially, with a short delay, asking the subject to make the lexical decision only on the second (target) stimulus.

Our expectations started from the consideration that, in principle, the negative priming could be quantitatively different, depending on the relative frequency of the stimuli. Consider, for instance, what might happen with two homographic stems, one very frequent and the other with a low frequency of occurrence: If the inhibitory strength is proportional to the frequency of the stimulus, then the high frequency stem should succeed in inhibiting the low frequency word, but the inverse should not happen. (On this view, the results of Experiments 1 and 2 could have been influenced in some way by the fact that the frequency of the individual items in each pair could not be controlled.) Alternatively, the inhibitory link might be activated independently of the frequency of the stimulus. In this case, we should find symmetrical inhibition.

An additional objective in the third experiment was to replicate the effect of neg-
ative priming using the same word stimuli in both the experimental condition and the control condition. The reason for this additional control was that we wanted to be sure that the effect of negative priming in Experiments 1 and 2 was not due to an inappropriate matching between stem homograph stimuli and control words.

Method

Stimuli

Fifteen pairs of homographic stem words were selected. Each pair consisted of a high frequency word (e.g., *finire* "to finish") and a low frequency word (*fina* "thin (feminine singular)"). The mean stem frequency of the set of high frequency words was 167 (Bortolini et al., 1971); in the set of low frequency words it was 13. The mean whole-word frequency was 93.3 for high frequency words, and 2.3 for low frequency words.

The 30 homographic stem stimuli were combined to form the first two experimental categories. In the first category (Cat.1: high frequency homographic stem, HFHS) the high frequency words were the targets and were preceded by their homographic mates as primes (e.g., prime: *fina*; target: *finire*). In the second category (Cat.2: low frequency homographic stem, LFHS) the low frequency words were the targets and were preceded by their homographic mate as primes (e.g., prime: *finire*; target: *fina*).

In order to create the appropriate control for both the experimental conditions, 30 control words with ambiguous stems were selected and matched with the 30 experimental words for stem and surface frequency, length, and form class. In two further conditions these words served as primes instead of the test items with which they were matched. Therefore, the third category (Cat.3: control high frequency homographic stem, CHFHS), the fifteen targets were the same homographic stem words of the first category, while the primes were the control, low frequency words (e.g., prime: *pafa* "shovel"; target: *finire*). In the fourth category (Cat.4: control low frequency homographic stem, CLFHS), the fifteen targets were the same low frequency homographic stem words of the second category, and the primes were the control, high frequency words (e.g., prime: *capire* "to understand"; target: *fina*).

Thus, each of the 30 experimental words was included in two experimental categories as target and in one experimental category as prime. We were interested in the contrast between the two categories in which the same words were employed as targets, alternatively preceded either by their stem homograph mates, or by the control words. Therefore, the two contrasts of interest were Cat.1 (HFHS) versus Cat.3 (CHFHS), and Cat.2 (LFHS) versus Cat.4 (CLFHS).

Mean length was 5.1 letters for both the HFHS and LFHS targets. The list of HFHS targets was composed of 10 nouns and 5 verbs; and the LFHS list included 8 nouns, 5 verbs, and 2 adjectives. Control primes had the following characteristics. For the low frequency primes (Cat.3), mean stem frequency was 11.5; mean surface frequency, 2; and mean length, 5 letters. Of these items, there were 8 were nouns, 5 verbs, and 2 adjectives. For the high frequency primes (Cat.4), mean stem frequency was 172; mean surface frequency, 87; and mean length, 5.2 letters. There were 10 nouns and 5 verbs in this list.

Since each target word was included in the whole list three times (twice as a target and once as a prime), we wished to avoid the presentation of the same experimental words several times during the experimental session. Therefore, each list of 15 experimental pairs was split into four sets (three sets of four pairs, one set of three pairs). Each subject was tested with one set from each experimental condition, for a total of 15 experimental stimuli (4 + 4 + 4 + 3) in which no stem was repeated. Four subjects, presented with the four different sets
PRIMING HOMOGRAPHIC STEMS

of experimental stimuli, formed a supersubject.

Each subject was also tested with 125 word targets (preceded in 55 cases by a word prime and in 70 cases by a nonword prime) and 140 nonword targets (preceded in 70 cases by a word prime and in 70 cases by a nonword prime), for a total of 280 target stimuli.

In all, there were 280 nonwords employed in this experiment. The procedure adopted to construct the nonwords was the same as in Experiments 1 and 2. The nonwords were derived from a set of base words comprised of 98 verbs, 130 nouns, and 52 adjectives, reflecting the distribution (by length, frequency, and form class) of the 280 word stimuli. (Half of the nonwords served as targets and half as primes in this experiment.) All of the nonwords ended in a legal suffix. Fifty-five nonwords contained a multiletter verbal inflection, while 35 contained a nominal or adjectival derivational suffix.

Materials and Equipment

These were as in Experiments 1 and 2.

Procedure

The prime stimulus was presented in the center of the screen for a period of 150 ms, and it was followed in the same position after a delay of 50 ms by the target stimulus.

Subjects were required to make the lexical decision only on the target item. They were also instructed to respond as fast and as accurately as possible. They responded by pushing one button when they recognized the target item as a word, and another when they considered the target a nonword. Subjects had to respond before a preset limit of 1 s. The interval between the disappearance of a target stimulus and the presentation of the subsequent prime was 1 s.

Reaction times were measured from the onset of the target to the time the subject pressed the response button. The stimuli were organized into five blocks of 56 prime target pairs. No experimental word was included in the first four pairs of a block. The total pool of 280 stimuli, arranged in four different random orders, was presented to all the subjects, after two blocks of 30 practice trials each.

The other aspects of the procedure were the same as in Experiments 1 and 2.

Subjects

Eighty subjects completed the experiment, for a total of 20 supersubjects. They served for one session lasting about 40 min and they were paid for their participation in the experiment.

Results

Mean reaction times and percentages of errors are shown in Table 3. High and low frequency targets were respectively 33 and 39 ms slower when preceded by a stem homograph than when preceded by an unrelated prime; and high frequency targets were respectively 62 and 56 ms faster than low frequency targets in the stem homograph and control priming conditions. The results of a two-way analysis of variance (priming X frequency), by items and by subjects, showed a main effect for type of priming (MinF(1,132) = 6.95, p < 0.01) and frequency (MinF(1,132) = 8.99, p < 0.005) for reaction times, and an equally strong effect of frequency on errors (MinF(1,130) = 20.6, p < 0.001). There was no interaction in the analyses on either reaction times (by subjects, F(1,76) = 0.59) or errors (by subjects, F(1,76) = 0.56). The elevated er-

<table>
<thead>
<tr>
<th>Targets</th>
<th>Stem homographs</th>
<th>Controls</th>
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<tbody>
<tr>
<td>High frequency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>595</td>
<td>562</td>
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<tr>
<td>% errors</td>
<td>7.3</td>
<td>5.3</td>
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<tr>
<td>Low frequency</td>
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</tr>
<tr>
<td>RT</td>
<td>657</td>
<td>618</td>
</tr>
<tr>
<td>% errors</td>
<td>31.3</td>
<td>25.7</td>
</tr>
</tbody>
</table>

TABLE 3
EXPERIMENT 2
ror rate for the low frequency words reflects the fact that in order to match the stimuli on dimensions of relevance we had to include some rather uncommon words. Thus, while the accuracy rate on low frequency targets admittedly renders the reaction time data for these stimuli somewhat problematic, the fact that the error rate differences are also in the predicted direction for the two priming conditions provides some encouragement that the reaction time difference is reliable. More important, though, is the fact that the high frequency targets are significantly affected by priming condition. That is, the high frequency stems are inhibited by their low frequency homographs.

The results on homographic stem pairs clearly confirm those reported in Experiments 1 and 2, even with a delayed presentation (200 ms) of the two items, and in the presence of a control against the same target in matched, nonhomograph conditions. These results also allow us to reject the hypothesis that inhibition between stem homograph pairs is asymmetric and is governed by the effects of word frequency. The absence of an interaction between frequency and type of priming—i.e., the absence of differential inhibition as a function of the relative frequency status of the prime and target—indicates that low frequency stems inhibit high frequency homographic stems as effectively as high frequency stems inhibit their low frequency homographs.

**General Discussion**

The results of our experiments provide strong support for morphological decomposition in lexical processing. Reliable inhibition effects were found for pairs of stem homographs {bust-a “envelope,” bust-o “corset”} when compared with pairs of orthographically related words {colp-o “neck,” coll-o “blow”} (Experiments 1 and 2), or with pairs of unrelated words {busta, colpo} (Experiments 2 and 3); and these effects were found when the paired items were presented simultaneously (Experiments 1 and 2) or sequentially (Experiment 3). However, performance on pairs of orthographically related words did not differ from performance on pairs of unrelated items (Experiment 2). Facilitation effects were found for semantic relatedness (Experiment 1) and morphological relatedness (Experiment 2). Finally, the inhibition effects found for stem homograph pairs were not attributable to the ambiguity of the stems, since the stems were similarly ambiguous in the orthographically similar (Experiments 1 and 2), morphologically related (Experiment 2), and unrelated word pair conditions (Experiment 3).

These findings are noteworthy for several reasons. There have been results on word stimuli reported previously that are cited as support for morphological decomposition in lexical access; but these have often been challenged as derivable from purely semantic and/or orthographic properties. The reliable pattern of results with word stimuli that we have obtained are not subject to these criticisms. Specifically, the effect of homographic stems on lexical decision cannot be accounted for in terms of the amount of orthographic overlap between pairs of words, since the inhibition found for the stem homographs did not occur for matched pairs of words that were orthographically similar at the word level. Instead, it is necessary to posit a level of representation in the course of lexical access at which words are represented in terms of their constituent morphemes. The effect can only be accounted for in terms of these morphemic constituents. Thus, our data are not compatible with the class of models of lexical access which do not distinguish among morphologically related (e.g., {colpa “fault,” colpe “faults”}), stem homographs (e.g., {colpa “fault,” colpo “blow”}), and orthographically similar (e.g., {colpa “fault,” colla “glue”}) word pairs in terms of morphemic structure, since the observed contrasts cannot be stated in terms of orthographic and mor-
phosemantic relatedness alone. These results allow us to reject, for example, models of lexical access such as that in McClelland and Rumelhart (1981) wherein letter and word levels are postulated, without intermediate units and with inhibitory links among representations in each level. As we have seen, the simple assumption of inhibitory links between whole-word representations is not sufficient to explain our data. That is, the word based results presented here constitute transparently interpretable support for the morphological decomposition hypothesis.

In addition, these results provide support for a number of more specific assumptions of the AAM model of lexical access. In particular, they support the distinction between lexical (morphemic) representations, on the one hand, and word and morpheme based access procedures for those representations on the other. Consistent with the predictions of the AAM model, the morphemic effect of inhibition induced by stem homographs is not dependent on the whole word frequency effects identified with the access procedures, suggesting different loci for these effects: lexical versus orthographic. These results converge rather nicely with data from stem and surface frequency experiments (e.g., Taft, 1979; Burani & Caramazza, 1987) and priming studies (e.g., Stanners et al., 1979; Fowler et al., 1985) in support of the morphological decomposition hypothesis. Furthermore, the present experiments and collateral results from nonword experiments (Caramazza et al., 1988) indicate that lexicality decisions are a function of the kind of relationship that exists between the morphemes which comprise a stimulus word; and that this function is expressed, in the case of visual presentation, at the level of the orthographic input lexicon. We have suggested that inhibition effects appear when the activation of a homographic stem provides conflicting information regarding the combinatorics of the stem in the stem + affix sequence. These same mechanisms are motivated by the nonword data in that they are needed to accommodate the effect on nonword rejection performance of morphological decomposability, as well as in the effect of varying degrees of satisfaction of the requirements of combinability of morphemes. For example, when a nonword is composed of a suffix and a suppleted, but otherwise appropriate, stem, rejection times are longer than for stem + affix combinations that cross conjugation (Caramazza et al., 1988). Thus, both the word and nonword results affirm the hypothesis that stem representations are linked to sets of appropriate affixes by a number of grammatical features (form class, conjugation type, gender, number, etc.), and that the process of lexical decision must be taken to involve the use of information about the combinability of the accessed morphemes.

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