

The Quarterly Journal of Experimental Psychology Section A

ISSN: 0272-4987 (Print) 1464-0740 (Online) Journal homepage: <http://www.tandfonline.com/loi/pqja20>

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To cite this article: Remo Job & Giuseppe Sartori (1984) Morphological decomposition: Evidence from crossed phonological dyslexia, *The Quarterly Journal of Experimental Psychology Section A*, 36:3, 435-458, DOI: [10.1080/14640748408402171](https://doi.org/10.1080/14640748408402171)

To link to this article: <http://dx.doi.org/10.1080/14640748408402171>



Published online: 29 May 2007.



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Morphological Decomposition: Evidence from Crossed Phonological Dyslexia

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In this paper we report some clinical data relevant to the issue of whether or not words are decomposed into their constituent morphemes prior to lexical access during reading. The data were obtained from a crossed phonological dyslexic patient who produced many derivational errors in reading aloud. The experimental investigation consisted of a series of tests requiring either reading words and non-words aloud or lexical decision tasks. The results are interpreted as supporting decomposition models of lexical access. In particular, a revised version of the logogen model—which postulates visual recognizers for affixes—seems to fit the data very well.

GENERAL INTRODUCTION

Two basic hypotheses have been proposed to account for the processing of affixed words in print. The first states that this type of word is decomposed into its constituent units—i.e. root morpheme and affixes—in order to access the mental lexicon. Two versions of this hypothesis (cf. Manelis and Tharp, 1977), called, respectively, the decomposition-first and decomposition-second hypotheses, have been proposed. According to the former, when processed, all words are decomposed into bases and affixes; a test is then performed to determine whether the base and the (possible) affixes are valid as a combination; if not, a lexical search for the word as a whole is then performed. According to the decomposition-second hypothesis, lexical search for the item as a whole is first performed, but this search fails for affixed words, which are not stored as single units. Further processing is therefore necessary for these words; they are decomposed and the combination re-tested at a further stage.

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Thanks are given to C. Barry, M. Coltheart, R. J. Jarvella, J. Masterson, V. Rosenthal and two anonymous referees for many insightful comments on an earlier draft of this paper. We are also grateful for the assistance of Jacqueline Masterson in translating the paper.

The alternative hypothesis, called the single-unit hypothesis, states, instead, that each affixed word is stored as a single unit, and that lexical access involves the search and retrieval of the whole unit. Clearly, in the first case storage economy is emphasized, while in the second it is processing economy that is emphasized.

Evidence favouring the decomposition hypothesis has been presented by, among others, Murrell and Morton (1974) and Taft and Forster (1975; cf. also Taft, 1979, 1981). Murrell and Morton used a tachistoscopic recognition task. The subjects were required to memorize a list of words and were then presented with words that were either (a) identical to some of the previously presented words (e.g. word in the memorized list: *car*; word in the recognition set: *car*), (b) morphologically related (e.g. *car*, *cars*), (c) visually and acoustically similar (e.g. *car*; *card*) or (d) unrelated. The results showed facilitation for both identical and morphologically related words but not for visually similar and unrelated words. Taft and Forster (1975) used a lexical decision task in their experiment. The critical stimuli in their study were non-words that were either stems of prefixed words (e.g. *juvenate*, from *rejuvenate*) or pseudostems of pseudoprefixed words—i.e. words beginning with a string of letters identical to a real prefix (e.g. *pertoire*, from *repertoire*). If morphological decomposition takes place, the authors argue, words such as *rejuvenate* should be stored in the lexicon as *juvenate*, and so stems such as *juvenate* should require a longer time to classify as non-words than pseudostems such as *pertoire*. The results showed this to be the case, since the latter type of stimuli produced faster reaction times than the former. In addition, there were 17% errors of classification for items like *juvenate* and only 4% for items like *pertoire*. A similar pattern of results has been obtained in an experiment in which Taft and Forster constructed the non-word stimuli using inappropriate prefixes with real stems (e.g. *dejuvenate*) and pseudostems (e.g. *depertoire*).

However, predictions derived from the morphological decomposition model have not always been confirmed in subsequent studies, and the argument has been advanced that Taft and Forster's (1975) data may have been the result of a special strategy induced by the set of stimuli used in their experiment (cf. Rubin, Becker and Freeman, 1979).

The single-unit hypothesis has been experimentally tested by Manelis and Tharp (1977). In the first of their experiments, these authors compared decision times for judging whether two simultaneously presented letter strings were both words or not, a task called double lexical decision. The critical stimuli were suffixed words (e.g. *darker*, *sender*) and pseudo-suffixed words—i.e. non-suffixed words ending in suffix-like forms (e.g. *sister*, *somber*). The predictions in this experiment were straightforward: If decomposition takes place, affixed words should require longer (according to the decomposition-second hypothesis) or shorter (according to the decomposition-first hypothesis) reaction times than pseudo-affixed words; if, on the other hand, words are represented as separate entries in the

lexicon, both types of words should require the same amount of time. No difference was found in the response times to pairs of pseudo-affixed words compared to pairs of affixed words; however, both conditions led to shorter response times than did conditions in which a suffixed and a pseudo-suffixed word were combined.

In the second experiment, subjects were required to decide whether an initially displayed word (e.g. *kiss*) was contained in the item that followed. On some of the trials this item was an affixed word (e.g. *kissing*, *hissing*), on the other trials it was an affixed non-word (e.g. *kissen*, *hissen*). The results showed a reaction time advantage for words over non-words, indicating that the subjects could not decompose the test items and process the bases alone. Manelis and Tharp interpret the results of both experiments as supporting the single-unit hypothesis. There are, however, some problems with the stimuli used and with some of the results, which greatly weaken this interpretation. In fact, as Taft (1979) points out, the distribution of suffixes in the second experiment is different for words and non-words in that suffixes for the former are very frequent, while those of the latter are much less frequent. In addition, as we have seen, at least one of the findings is at odds with the hypothesis of single entries, i.e. the longer reaction time in the combined than in the "pure" condition in Experiment 1.

Some neuropsychological evidence is also available on the issue of morphological decomposition versus single-unit entries. Patterson (1980) analysed derivational paralexias of two neurological patients with deep dyslexia (Coltheart, Patterson and Marshall, 1980) in order to test predictions derived from unitary and decomposition models of the lexicon. Examples of derivational paralexias made by the patients are the substitution of "projector" for *projection* and "apart" for *parting*. Patterson's patients were required to perform reading-aloud and lexical decision tasks. In the first test (test A), a list of letter strings was used such that a root-morpheme was associated with an appropriate suffix (e.g. *nearest*) half of the time and with an inappropriate one (e.g. *fearest*) the rest of the time. The results showed that the patients were very poor at reading suffixed words and that most of the errors occurred on suffixes; that is, while base morphemes were for the most part read correctly, suffixes were very often substituted or deleted. In the second test, the aim was to investigate the effect of real suffixes, since the performance of one of the patients on lexical decision in the first test was poor, and the decrement might have been due to the presence of real suffixes, independent of the nature of the base letter string. Thus, test B consisted of 35 suffixed words (e.g. *hardest*) and 35 suffixed non-word bases (e.g. *neakest*). Lexical decision performance on test B was excellent for one patient and fairly good for the other; since this represented an improvement over test A levels of discrimination for both patients, poor performance on test A could not be attributable solely to the fact that every letter string had a suffix. However, the only moderate

performance of one of the two patients still left the possibility that word/non-word discriminability was reduced by the presence of suffixes. Thus one further test was devised based on every base non-word for which a patient had given a false positive response to the suffixed form in the preceding test, as well as on every base word for which a patient had missed the suffixed form in any of the two preceding tests. For example, since one of the patients had incorrectly accepted the letter strings *firching*, *drowed* and *loundest* in test B, test C included the letter strings *firch*, *drow*, and *lound*. In addition, the patient had wrongly classified *feared*, *ageing*, and *kingly* as non-words in test A, so test C also included *fear*, *age*, and *king*. The performance on base words on this test was better than that on the corresponding suffixed words of test B. In addition, the patient who in test B had accepted as words some suffixed non-words (e.g. *firching*) was less likely to accept the corresponding base non-words (e.g. *firch*) as words.

Discussion of the results in terms of the specific model proposed by Patterson (1980, 1982) will be postponed until the general discussion. It is sufficient to note here that Patterson's data from the three tests are compatible with predictions derived from models of lexical access that assume decomposition of words into their constituent morphemes.

It seems, then, that the evidence offered to support either the decomposition model or the unitary model is not unequivocal. In the present paper we report some clinical data bearings on this issue obtained from a patient who produces many derivational errors in reading aloud.

Case Report

Leonardo, a 33-year-old Italian male, was admitted to the Department of Neurology of Treviso General Hospital in September 1981. Neurological examination on admittance revealed a severe left hemiparesis. The patient also manifested language difficulties. CT brain scan revealed an extensive infarctual area in the front temporal region of the right hemisphere. Carotidography showed a kinking of the right and left internal carotids. Four days after admittance, his oral production was still greatly impaired, and for this reason extensive neuropsychological testing was started. The basic findings of this can be summarized as follows: On the WAIS the patient obtained a verbal IQ of 80, a performance IQ of 68, and an overall IQ of 73; he was right-handed as assessed by the Edinburgh Inventory, as were his relatives; his oral expression was agrammatic, with articulatory difficulties; naming was poor and so was repetition of both words and non-words; comprehension of single spoken words was good as assessed by a picture/spoken word matching task; sentence comprehension was also relatively good, as shown by the Token Test score (24/36).

Two weeks after admittance, Leonardo's language pattern was similar to that of a Broca's aphasic. Reading and writing were both impaired; on

reading aloud a list of 40 words all 5 letters in length, he was correct 72.5% of the time; on a list of 80 words in which word length varied, he made 20 errors. The errors consisted mainly of visual, semantic and decomposition errors. While the majority of semantic errors had a visual component, some had not. Examples of these are: *difesa* [defense]→“sfida” [challenge]; *brodo* [broth]→“dado” [stock cube]; *vocazione* [a calling to priesthood]→“visione” [vision]; *intorno* [around]→“dentro” [inside]. On reading aloud a list of 40 non-words all 5 letters in length, he scored 2.5% correct; in other lists of non-words his accuracy ranged between 0 and 4%. The patient performed well on a lexical decision task with visually presented nouns ($d' = 2.59$); he also performed well on reading single letters (9/10 correct). As semantic errors and a part-of-speech effect (which did not include low performance on function words) were observed in the patient's reading aloud of words, it was concluded that the constellation of symptoms represented the acquired reading disorder known as deep dyslexia (see Coltheart, Patterson, and Marshall, 1980, for a review of the syndrome).

When a further four weeks had elapsed after the initial assessment, the patient's oral language had improved markedly; and when the tests reported in this paper were carried out, he could speak more fluently, even if some syllable repetition and articulatory difficulties were still observed. Minor but very important changes in his reading and writing patterns were also observed, the most important of these being that semantic paralexias were no longer produced, although non-word reading was still very poor. Thus Leonardo's reading pattern appeared to have shifted from the initial deep dyslexia to phonological dyslexia. This temporal course of an initial crossed deep dyslexia to phonological dyslexia has a relevant theoretical interest, but that will not be discussed here. It is worth mentioning, however, that responses to non-words changed with the disappearance of semantic paralexias: omissions and unblended letters in response to non-words were replaced by visually similar words or non-words.

Decomposition Errors

In reading aloud isolated words during the course of the neuropsychological examination the patient produced many errors, as we have already noted. Most of these were paralexias that authors working on acquired dyslexias have categorized as derivational, since in reading the stimulus patients delete, substitute or insert affixes while preserving the root morpheme. Many examples of these kinds of error are reported in Coltheart, Patterson and Marshall (1980, Appendix 2). However, the term “derivational error” seems to us to fail to capture the distinction linguists draw between derivation and inflexion and may therefore be misleading. In addition, close examination of our patient's error corpus shows that

Table I

Example of Decomposition Errors Taken from Leonardo's Corpus of Errors

| Prefix | | Base | | Suffix | | Example | |
|--------|----|------|----|--------|----|---------------|----------------|
| S. | R. | S. | R. | S. | R. | S. | R. |
| + | + | + | + | + | + | ri/ved/ono | →ri/ved/ono |
| + | - | + | + | + | + | ante/pong/ono | →pong/ono |
| + | - | + | + | + | - | ri/alz/are | →alz/a |
| + | + | + | + | + | - | ri/guard/ato | →ri/guard/a |
| - | + | + | + | + | + | somm/a | →in/somma |
| - | - | + | + | + | - | legn/o | →legn/ame |
| + | + | + | - | + | + | ri/guard/are | →ri/and/are |
| + | + | + | - | + | - | com/prend/ere | →con/divid/ono |

S = stimulus presented to the patient.

R = reading response given by the patient.

+ = that part of word is present in the stimulus or in the response.

- = that part of word is either absent in the stimulus or deleted or substituted in the response.

this kind of error may involve change to the root morpheme as well as to the affix. We prefer to consider change of the root morpheme as similar to affix changes and not to treat them as visual errors, for the same reasons Patterson (1980) distinguishes between visual and derivational errors. It seems that the label "decomposition error" better expresses the fact that the morphological components of words are quite independent sources of these errors; we will therefore use this term to refer to the so-called derivational errors plus morpheme substitutions. From this perspective, a decomposition error arises whenever, in reading aloud, a prefix is substituted, inserted or deleted, a root stem is substituted or a suffix is substituted, inserted or deleted. In Table I the logical possibilities of occurrence of decomposition errors in Italian, which is a language whose words are always suffixed, are summarized, and examples derived from our patient's error corpus are given for each occurrence.

EXPERIMENTAL INVESTIGATION

Reading Tasks

The first series of tasks was devised to investigate the reading ability of the patient, on the assumption that if his decomposition mechanism was impaired, he should have shown a dissociation in reading affixed and non-affixed words.

Table II

Forms in the Present Tense Conjugation of Two Verbs in Italian

| Irregular verb | Regular verb |
|----------------------|--------------------------|
| Andare [to go] | Mangiare [to eat] |
| io vado [I go] | io mangio [I eat] |
| tu vai [you go] | tu mangi [you eat] |
| egli va [he goes] | egli mangia [he eats] |
| noi andiamo [we go] | noi mangiamo [we eat] |
| voi andate [you go] | voi mangiate [you eat] |
| essi vanno [they go] | essi mangiano [they eat] |

Task 1

Verbs in Italian have a very rich inflectional system: For each verb there exist more than 40 inflected forms. These are generated by adding to the root morpheme of the infinitive form suffixes congruent for person and tense. There are, however, some “irregular” verbs that do not follow this general rule. Each of these verbs has two types of inflected forms: regular, formed with the root morpheme of the infinitive, and irregular, where the root morpheme is different from that of the infinitive. For each irregular verb, the number of regular inflected forms is usually greater than the number of irregular forms, even if regular forms may occur less frequently within a given conjugation. This is illustrated by the example of an irregular verb reported in Table II, where there are two regular inflected forms but four irregular inflected forms in the present tense.

Given the different occurrences of regular and irregular forms and the fact that most of the irregular forms are either unique or have a root-morpheme common to only a few forms, we assumed that only regular forms of irregular verbs can be productively stored as root morpheme plus affixes. It was hypothesized therefore that Leonardo should have been more likely to make decomposition errors to the regular forms than to the irregular forms of irregular verbs.

Material

A list of 99 items was constructed. Each of the 33 irregular verbs used appeared three times in the list, once in the infinitive form, once in a regular inflected form, and once in an irregular inflected form. Presentation was balanced, so that for 1/3 of the verbs the infinitive form was presented first, for 1/3 the irregular form was presented first, and for the remaining 1/3 the regular form was presented first. In addition, care was taken that different forms of the same verb should never appear next to each other.

Results

Leonardo correctly read 23 of 33 infinitive forms. Of the inflected forms, he correctly read 15 of 33 irregular and 6 of 33 regular forms. The Bulmer

Table III

Error Types in Reading Verbs Aloud

| | Type of Stimulus | | |
|--|--------------------|-----------------|-------------------|
| | Verbs in: | | |
| | Infinitive Form | Regular Form | Irregular Form |
| Omission | 0 | 6 | 5 |
| Suffix substitution | 2 | 9 | 3 |
| Morpheme substitution | 4 | 2 | 0 |
| Prefix and suffix substitution | 1 | 1 | 0 |
| Visual errors | 3 | 9 | 7 |
| Exchanging irregular and regular form | 0 | 0 | 3 |

(1967) test, which will be used to test all differences between percentages, showed this difference to be statistically significant ($d = 2.37$, $p < 0.02$). As far as decomposition errors are concerned, 12 out of 27 errors to regular forms are of this type, while only 3 out of 18 errors to irregular forms are of this type ($d = 3.03$, $p < 0.01$). A qualitative analysis of errors is shown in Table III.

From the table it is clear that suffix substitution is mainly observed in response to regular forms. Moreover, it is worth noting that all 14 suffix substitution errors are legal substitutions of suffixes. Examples of suffix substitutions to irregular verbs are shown in Table IV, and some examples of morpheme substitution are shown in Table V. Finally, two examples of "switching to regular form", where the patient gives a wrong response to an irregular form by reading it as a regular form or in the infinitive, are shown in Table VI.

Decomposition errors are very often visually similar to the target, and it is therefore important to try to demonstrate that they are not, in fact, visual errors rather than errors indicative of impairment to the mechanism

Table IV

Suffix Substitutions to Irregular Verbs

| Stimulus | Response | Infinitive |
|----------------------------------|-----------------------|-------------------------|
| <i>decisi</i> [I decided] | "deciso" [decided] | decidere [to decide] |
| <i>uccisero</i> [they killed] | "ucciso" [killed] | uccidere [to kill] |

Table V

| <i>Morpheme Substitution</i> | |
|------------------------------------|------------------------------|
| Infinitive | Response |
| <i>ricord/are</i> [to remember] | → “tard/are” [to be late] |
| <i>piang/ere</i> [to cry] | → “piac/ere” [to like] |
| <i>accend/ere</i> [to turn on] | → “attend/ere” [to wait] |
| <i>conosc/ere</i> [to know] | → “corr/ere” [to run] |
| Regular Form | Response |
| <i>guard/ati</i> [looked] | → “cerc/ati” [searched] |
| <i>scend/evo</i> [I came down] | → “scriv/evo” [I wrote] |

involved in morphological decomposition. We attempted to do this by comparing Leonardo’s performance in reading aloud the list of irregular verbs with that of Beatrice, another phonological dyslexic, whose reading aloud is characterized by omissions and many visual errors but not by derivational errors. If Leonardo’s errors to the regular and irregular forms of irregular verbs are indeed due to an impairment of the mechanism for morphological decomposition and not to visual errors, and if this impairment entails an increased rate of errors to regular rather than irregularly inflected forms, then we would not expect Beatrice to show the difference in reading aloud the regular and irregular forms that was observed in Leonardo. Indeed, Beatrice did not make significantly more errors to regular than to irregular forms, her correct responses being 6/33 and 11/33, respectively ($d = 1.36$, n.s.); in particular, decomposition errors to regular (4/27) and irregular (3/22) forms do not differ.

Table VI

| <i>Irregular Form Read as Regular Form</i> | |
|--|---------------------------------------|
| <i>rispose</i> [he answered] | → “rispondesse” [he should answer] |
| <i>convinse</i> [he convinced] | → “convincere” [to convince] |

Leonardo's high error rate to regular forms and the pattern of substitutions observed point to a strong "dissociation" between the two classes of forms; according to our hypothesis, this indicates that while regular forms are "computed" after prelexical decomposition, irregular forms do not undergo decomposition but are, rather, stored as single units.

In order to test the generality of this finding, we constructed a list of words comprised of prefixed nouns, adjectives and verbs and asked the patient to read them aloud.

Task 2

Material

A list of 30 words was prepared, half of them words with a real prefix—e.g. *ripreso* [retaken]—the other half pseudo-prefixed words—e.g. *ritardo* [retardation]. Each group contained 8 nouns and 7 verbs matched for length and frequency.

Results

Accuracy on prefixed words was 20%, while on pseudo-prefixed words it was 53.5% ($d = 1.9, p < 0.05$). An analysis of the wrong responses showed that for prefixed words, prefixes were read correctly 35.7% of the time; for pseudo-prefixed words, pseudo-prefixes were read correctly 57.1% of the time ($d = 1.18, n.s.$). A decomposition error occurred only once to a pseudo-prefixed word, but there were 16 instances of this type of error to prefixed words. The decomposition errors observed in prefixed words include prefix substitution (e.g. *pre/visione* → "re/visione"), prefix deletion (and suffix change) (e.g. *ri/alzare* → "alza"), and root-morpheme substitution (e.g. *ri/accolto* → "ri/calco"). The decomposition error observed on the pseudo-prefixed words was a substitution of a word by another pseudo-prefixed word (*ricordo* → "ritardo").

Again, a better performance on non-affixed words with respect to affixed ones is observed. This strongly suggests that (a) decomposition does indeed take place in reading, and (b) Leonardo's morphological processing system is impaired. However, the pattern obtained could be explained in more than one way; in particular, either the decomposition-first or the decomposition-second hypothesis could account for the results. According to the latter hypothesis, the stimulus word presented to the patient is matched against a possible entry in the mental lexicon. If such an entry exists, then the response can be emitted; if not, the word is decomposed, and the entry corresponding to the root-morpheme is searched for. In this framework, our results could easily be explained by assuming that only affixed words undergo the decomposition process, while non-affixed and pseudo-affixed words are stored as single units; since Leonardo's decomposition mechanism is impaired, more errors are observed with affixed items.

The decomposition-first hypothesis can explain the same results, albeit

in a less straightforward way. Let us assume that the decomposition errors can arise at any of the following states: (a) when the affix is “stripped off” the stimulus word; (b) when it is processed by the system; (c) when a test is performed to determine whether the base and affix are valid as a combination. Let us also assume, as this hypothesis claims, that both prefixed and pseudo-prefixed words are decomposed prior to the access to the mental lexicon. If Leonardo is impaired at stage (c), we will expect him to make as many errors to affixed as to pseudo-affixed words; however, if he can compensate for his impairment by “guessing” a possible affix, he should make many errors, in particular many suffix substitutions, to affixed words, which can usually take several different affixes but should have very few choices for pseudo-affixed words, for which only one affix usually exists. This interpretation would be compatible with the experimental result obtained by Taft (1981), who showed that it takes longer to judge that a pseudo-prefixed word is a word than it takes to judge that a prefixed word is a word.

It is very difficult to design a possible test to decide between the two alternative hypotheses; however, we thought it was possible to devise a test that could falsify the latter hypothesis by focusing on the affix substitution strategy. If we present Leonardo with stimuli whose affixes cannot be substituted, and he does substitute them, we should conclude that that particular hypothesis was wrong. In order to do this, we exploited Leonardo’s inability to read aloud non-words.

Task 3

Material

A list of 29 non-words formed by a real prefix and a non-word was constructed. Two aims guided the choice of these stimuli: the first was to try to falsify the decomposition-first hypothesis along the lines mentioned above; the second was to test the prediction that items were, indeed, decomposed. In fact, if Leonardo treats our prefixed non-words as single entries, he should not be able to read them, as he is unable to read any other non-word. However, if he decomposes them, he should be able to read the (real) prefixes better than the (false) root morphemes.

Results

Leonardo correctly read 3 out of 29 of the strings. Errors in reading the strings were: producing visually similar words, 14/26; producing visually similar non-words, 6/26. The remaining errors (6/26) were due to sounding out syllables that were incorrect with respect to the stimulus. Analysis of the wrong responses shows that—as predicted—prefixes were read correctly 76.9% of the time, while false root-morphemes were correctly read 7.6% ($d = 5.34$, $p < 0.001$) of the time. Moreover, the patient never substituted one prefix with another.

Task 4

This task is similar to the previous one, except that reading suffixes is also tested.

Material

Each of the 34 non-words presented in this task was composed of a real prefix, a false root morpheme and a real suffix (e.g. *ri|tro|avamo*). The strings were 7 to 9 letters long.

Results

Only one string was read correctly. Errors consisted of the production of visually similar words (2) and non-words (12); the remaining 19 were due to sounding out syllables that were incorrect with respect to the stimulus. Inspection of these errors shows that, as in the preceding task, some parts of the non-words are more likely to be read correctly than others. So, prefixes were read correctly 23/34, suffixes were read correctly 9/34, and false root morphemes were read correctly 3/34. The difference in accuracy in reading prefixes and false root morphemes is significant ($d = 4.98$), as is the difference in reading suffixes and false root morphemes ($d = 1.91$, $p < 0.05$). Finally, it should be noted that the difference in reading prefixes and suffixes is also significant ($d = 3.39$). In this task, as in task 3, there were no prefix substitutions, and suffix substitutions occurred for only two items.

We interpreted the better performance on affixes in the last two tasks as evidence for the decomposition of stimulus non-words into their constituent morphemes and for their separate processing. If this is correct, it should follow that performance on non-words composed of a real affix and a real root-morpheme should be better than performance on non-words that cannot be decomposed in a meaningful way. The next task was designed to test this prediction.

Task 5

This task investigated the reading of non-words composed of an affix and a noun in illegal association.

Material

Two lists were constructed. The first contained 15 stimuli formed by an illegal association of prefixes and nouns—(e.g. *rileone* [re|lion] and *presedia* [pre|chair])—and their control strings formed by changing a letter both in the prefix and in the root stem of the experimental items. The second contained 20 stimuli formed by an illegal association of suffixes and nouns—e.g. *aranciando* [orange|ing])—and 20 control strings obtained by changing a letter in the root morpheme of the experimental items. The two lists were presented to Leonardo on different occasions.

Table VII

Accuracy (% Correct) in Reading Prefixed (List 1) and Suffixed (List 2) Non-Words

| | | Over-all | Prefix | Root-morpheme | Suffix |
|--------|---|----------|--------|---------------|--------|
| List 1 | E | 46.6 | 66.6 | 66.6 | — |
| | C | 6.6 | 33 | 6.67 | — |
| List 2 | E | 10 | — | 50 | 35 |
| | C | 0 | — | 0 | 10 |

E = experimental strings.

C = control strings.

— = not tested.

Results

A summary of the correct responses is presented in Table VII. As predicted, Leonardo's ability to read non-words increases if they contain a real affix. As in task 4, an asymmetry was again observed between accuracy in reading prefixes and suffixes. This could be due to the fact that, on average, words in Italian have a greater range of suffixes than prefixes that can be associated with them.

The results obtained thus far clearly point to the fact that decomposable words are read with greater difficulty than nondecomposable words (tasks 1 and 2), but also that parts of decomposable items are read better than control items (task 3 and 4); in addition, it seems that Leonardo has some knowledge of specific noun/affix associations (task 4). These findings seem to suggest that affixes may be represented in a way not dissimilar from that of root morphemes. If this is true, Leonardo should be able not only to read affixes, but also to understand them when presented in isolation. We therefore selected a set of affixes and tested Leonardo's comprehension of them.

Task 6

This task investigated comprehension of prefixes and suffixes in addition to reading aloud.

Materials

Nine real prefixes and suffixes, 3 to 6 letters long, were selected; the corresponding 9 control non-words were derived by changing one letter in each affix. Since Italian affixes have meaning but are not words that exist by themselves, the list presented to Leonardo was composed of 18 non-words. The items were presented to the patient visually one at a time and he was required to read them silently. Then a recognition set was auditorily presented. Each set contained three items: (a) a synonym of the stimulus, (b) the word "nothing" and (c) an unrelated word. For

Table VIII

Accuracy (% Correct) in Reading Aloud and Comprehension of Affixes Presented in Isolation

| Test stimuli | Reading aloud | Matching to correct alternative | Verbal definition |
|-----------------------|---------------|---------------------------------|-------------------|
| Prefixes and suffixes | 88.8 | 77.7 | 44.4 |
| Control non-words | 22.2 | 33 | — |

example, *issimo* [very] was presented with the three alternatives (a) *niente* [nothing], (b) *molto* [very], and (c) *buono* [good]. The patient's task was to choose the correct answer among the three alternatives (in the case of non-words the correct answer was of course *niente* [nothing]). In a different session, the list was re-presented, and the patient was required to read the string aloud and to define each item orally.

Results

The results are summarized in Table VIII. Also, when presented in isolation, affixes are read better than control non-words. In addition, recognition accuracy is quite good for the former type of stimulus. This may be interpreted as evidence for comprehension of affixes presented in isolation. On the other hand, Leonardo's performance on control non-words is at chance level, and this seems to us to be the direct consequence of his inability to read non-words.

Lexical Decision Tasks

Material

A list of 20 suffixed nouns and verbs 6 to 9 letters long was used, together with 20 control non-words. Non-word characteristics were varied across tasks, so that some tasks, such as 7, 8, and 9, had the same word stimuli but different non-words. In a different session the stimuli used in the lexical decision tasks were presented to the patient for reading aloud.

Task 7

Material

Non-words were derived by exchanging the suffix of two given words, so that for each non-word the morpheme and suffix were legal but were illegally associated.

Results

The patient correctly classified 18 of the 20 words and 12 of the 20 non-words, yielding a d' of 1.54. If d' is 0, then %Hits = % False Alarms (F.A.) and %Hits - %F.A. = 0. Testing the difference between %Hits and %F.A. is equivalent to testing whether d' is significantly different

Table IX

Type of Response in Reading Aloud Lists of Suffixed Words and Non-Words

| | Task 7 | | Task 8 | | Task 9 | |
|----------------------------|--------|----------|--------|----------|--------|----------|
| | word | non-word | word | non-word | word | non-word |
| Correct | 17 | 5 | 18 | 0 | 17 | 0 |
| Decomposition | 1 | — | 0 | 0 | 1 | 0 |
| Visually similar words | 0 | 8 | 0 | 8 | 0 | 6 |
| Visually similar non-words | 2 | 5 | 1 | 6 | 0 | 5 |
| Syllables | 0 | 0 | 0 | 3 | 0 | 7 |
| Others | 0 | 2 | 1 | 3 | 2 | 2 |

from 0. Therefore, for this d' , $d = 3.31$ ($p < 0.001$). Errors in reading aloud are summarized in Table IX.

The decomposition error was *scoprirvi* [to discover you (plural)] → “scoprivi” [you (singular) discovered]. Furthermore, a word classified as a word was read as a non-word, and another was classified wrongly but read correctly. A comparison between lexical decision on non-words and reading aloud the same non-words shows that of the 8 non-words classified as words in the lexical decision task, 4 were read as words and 4 as non-words. In addition, half of the 12 non-words correctly classified were read as words, while half were read as non-words.

Task 8

Material

Non-words were formed by changing one letter in the suffix of legal suffixed words.

Results

Leonardo correctly recognized 15 of the 20 words and 13 of the 20 non-words, with $d' = 1.06$ ($d = 2.54$, $p < 0.01$). Four words were classified wrongly but read correctly. A complete analysis of the reading data is shown in Table IX. A comparison between reading and lexical decision to non-words shows that the patient classified 7 non-words as words, and he read 5 of them as words and 2 as non-words. Of the 13 non-words he classified as non-words, he read 4 as words and 9 as non-words.

Task 9

Material

Non-words were derived by changing one letter in the root morpheme of the 20 suffixed words used in the two previous tasks.

Results

Leonardo correctly classified 14 words (out of 20) and 15 non-words (out of 20). The obtained d' was 1.20 ($d = 2.48$, $p < 0.006$). Two words wrongly classified were read correctly, and one was read with a derivational error. In Table IX a specification of the responses in reading aloud is given. The relation between reading non-words and lexical decision to non-words shows that all 5 non-words classified as words were read aloud as such, while only 1 of the 15 non-words classified as such was read aloud as a word.

Other lists directly comparing lexical decision and reading aloud were also used in tasks 10 and 11. These lists were composed of verbs only; again the main difference between the two tasks concerns the characteristics of non-words.

Task 10

Material

A list was used of 17 inflected verbs on which Leonardo had made a decomposition error during a previous session. The non-words were derived from the verbs by changing one letter in the root morpheme.

Results

A d' of 2.88 ($d = 3.96$, $p < 0.001$) was obtained in this task where all the verbs were classified correctly and 6 (out of 17) non-words were wrongly classified. Reading responses for words and non-words are reported in Table X. The 6 non-words wrongly classified were read as words, while 3 of the 11 non-words correctly classified were read as words.

Task 11

Material

The list was prepared with the same verbs used in task 10, but here non-words were derived by changing one letter in the suffix.

Results

Leonardo correctly classified all the verbs and wrongly classified only 2 of the 17 non-words. The obtained d' was 4.35 ($p < 0.001$). Responses in the reading task are summarized in Table X. The comparison of the reading and lexical decision tasks shows that the two non-words wrongly classified as words were read aloud as such, while of the 15 non-words correctly classified only 2 were read as words.

Task 12

Lexical decision on pseudoprefixed words and real prefixed words of the list used in task 2 was carried out.

Table X

Type of Response in Reading Aloud Lists of Verbs and Non-Words

| | Task 10 | | Task 11 | |
|----------------------------|---------|----------|---------|----------|
| | word | non-word | word | non-word |
| Correct | 11 | 2 | 13 | 5 |
| Decomposition | 6 | 0 | 4 | 0 |
| Visually similar words | 0 | 9 | 0 | 4 |
| Visually similar non-words | 0 | 3 | 0 | 6 |
| Syllables | 0 | 3 | 0 | 1 |
| Others | 0 | 0 | 0 | 1 |

Material

Two separate lists of 28 letter strings were given to the patient, the first list consisting of 14 pseudo-prefixed words and 14 non-words derived by changing one letter, the second of 14 prefixed words and 14 non-words.

Results

The d' for the pseudo-prefixed words was 1.49 (%Hits = 0.98, %F.A. = 0.66, $d = 2.15$, $p < 0.004$) while that of prefixed words was 0.88 (%Hits = 0.91, %F.A. = 0.67, $d = 1.55$, n.s.). As can be seen, discrimination is over-all above chance but far from the standard performance of this patient.

GENERAL DISCUSSION

Before turning to a discussion of the data, let us briefly summarize the main results of the experimental investigation, considering first Leonardo's reading performance and then his performance in the lexical decision tasks.

The patient is less accurate in reading regular forms of verbs than in reading irregular forms (task 1); he is also less accurate in reading prefixed words than in reading pseudoprefixed words (task 2). Despite his severe inability to read non-words, he is quite successful in reading non-words containing affixes. In particular, when presented with non-words formed by a false root morpheme and real affixes, he is more accurate in reading the affixes than in reading the false root morpheme (tasks 3 and 4). His superiority in reading morphologically valid parts of words is also evident when presented with non-words formed by illegal associations of affixes and nouns (task 5). Finally, Leonardo reads aloud and comprehends quite well affixes presented in isolation (task 6), even if isolated affixes are non-words in Italian.

Lexical decision was tested on five lists of words and non-words, the lists differing from each other mainly in the nature of the non-words. Table XI summarizes the findings of the lexical decision tasks.

Table XI

Summary of Results in the Lexical Decision Tasks

| Tasks and non-word types | Hits | F.A. | d' |
|---|------|------|------|
| <i>Task 7</i> | | | |
| Real root-morpheme and real suffix in illegal association | 0.90 | 0.40 | 1.54 |
| <i>Task 8</i> | | | |
| Real root-morpheme and false suffix | 0.75 | 0.35 | 1.06 |
| <i>Task 9</i> | | | |
| False root-morpheme and real suffix | 0.70 | 0.25 | 1.20 |
| <i>Task 10</i> | | | |
| False root-morpheme and real suffix | 1.0 | 0.25 | 2.88 |
| <i>Task 11</i> | | | |
| Real root-morpheme and false suffix | 1.0 | 0.35 | 4.35 |
| <i>Task 12</i> | | | |
| Pseudoprefixed non-words | 0.98 | 0.11 | 1.49 |
| Prefixed non-words | 0.91 | 0.67 | 0.88 |

Considered over-all, the data obtained from Leonardo seem to support the decomposition hypothesis rather than the single-unit-entry hypothesis.

A first important piece of evidence shows lexical decision to affixed nouns to be less accurate than to non-affixed words. Even more compelling is the data obtained from the lexical decision task performed on the list composed by prefixed and pseudo-prefixed words: d' to the former type of stimuli is 0.88, while d' to the latter is 1.49. Furthermore, on the five tests requiring reading aloud a just-classified (as word or non-word) letter string, there is a close parallel between reading and lexical decision on non-words. That is to say, if a string is classified as a word it is mostly also read as a word, while when it is classified as a non-word it is generally read as a non-word. In fact, a total of 94 non-words were presented in the five tests. Of these, 28 were wrongly classified as words, and 66 were correctly classified as non-words. Of the 28 items classified as words, 22 were read aloud as words, while of the 66 items classified as non-words, only 16 were (wrongly) read as words. This would rule out explanations of Leonardo's impairment in reading affixed words in terms of output problems. In fact, evidence for an output problem would consist of wrongly classifying a stimulus word as a non-word while reading it aloud with a decomposition error. This happens only once in 12 occurrences of decomposition error in the 5 lexical decision + reading aloud tests.

All the results seem thus to converge on one point; if a word is decomposable, it is more likely to be wrongly classified in a lexical decision task and misread as a decomposition error in reading aloud. This seems to be explicable only if it is assumed that decomposable items undergo morphological decomposition.

Evidence for this conclusion is also offered by the fact that the patient is able to repeat the lists of the five tasks correctly when they are presented auditorily, and in particular to repeat those stimuli which, when presented visually, give rise to decomposition errors.

All these findings seem to establish a direct link between prelexical decomposition and decompositional errors.

Let us now turn to the discussion of Leonardo's reading performance. When reading regular forms of verbs is compared with reading matched irregular forms, more errors are observed with the first type of stimulus (task 1). A similar pattern is present in reading real prefixed words and matched pseudo-prefixed words: accuracy is lower for the first type of stimulus (task 2). These facts indicate a selective impairment of the decomposition mechanisms and, again, are consistent with a model that assumes prelexical decomposition of decomposable items. Leonardo seems to be selectively impaired in such a process with respect to the single-entry access that is supposed to be used for irregular verbs and pseudo-prefixed words.

Our results are in agreement with those obtained by Patterson (1980), who found that suffixes cause enormous reading difficulty for deep dyslexic patients. Patterson (1980, 1982) proposes that the pattern of results she obtained can be accounted for by the logogen model. Following Morton and Patterson (1980), she assumes that the input visual logogens are sensitive to root morphemes, while affixes are recognized through some other route.

In her most recent paper, Patterson (1982) proposes that the processing of affixes and function words is preferentially carried out by means of a phonological recoding stage. The major evidence for this suggestion comes from the observation that deep and phonological dyslexic patients who are greatly impaired in phonological recoding are also impaired in reading function words and affixes. She notes, however, that while her patient, A.M., has no problems in lexical decision to function words, he performs poorly in judging the lexicality of illegally associated suffixed words (*nearest* vs. *fearest*). In the latter task, where $d' = 2.42$, A.M. shows an anomalous high false positive rate, denoting that he was not perfect in detecting when a suffix was presented in an illegal association. This result suggests that function words and affixes may require separate accounts.

Our patient, in a similar task (task 7), where stimuli of the type *alberello* vs. *alberava* were used, displays a similar pattern, but the d' is even poorer ($d' = 1.54$). It should be remembered, however, that in Italian inflections are compulsory, and the suffixes we used were infrequent ones. Neither

Patterson's nor our results are easily accommodated within Patterson's model.

Two other phenomena seem to be inconsistent with Patterson's model: root morpheme substitution and better performance in reading real affixes embedded in non-words with respect to control non-word parts. The first phenomenon, a type of error with affixes correctly read and legally associated with a substituted root morpheme so that the result is a genuine inflected word, seems to be explicable only if one assumes a similar processing for both affixes and root morphemes; the second shows that the phonological route is indeed impaired, but that this does not influence affix processing.

Patterson notes that the existence of a patient impaired in reading non-words but not in reading function words and with no derivational errors would constitute counter-evidence for her account of derivational errors and of performance with function words. It is important to observe that Leonardo is not impaired at reading function words. His accuracy in reading a list of 40 nouns, half of high and half of low frequency, is in fact lower than his accuracy in reading a list of high- and low-frequency words (72.5% vs. 80%), and, in general, no list of nouns presented to the patient showed a superior performance to that of function words. Therefore Leonardo reads function words as least as well as any other word. As Leonardo makes decomposition errors, it would seem that processing of function words and of affixes is functionally independent. Recently Funnell (1983) reported some data that seem to support this claim further. Her patient, in fact, showed an impairment of non-word reading in the absence of any effect of word-class on reading and made few derivational errors.

On the basis of these results, it seems to us that a satisfactory model should not involve the phonological processing of affixes; on the contrary, we propose that there exist separate visual recognition devices for root morphemes and affixes, and we postulate interconnections among them.

Consider now a modification of the Morton and Patterson (1980) logogen model for the processing of prefixed and suffixed words such as *ri-prend-eva* [retook (3rd person, singular)] shown in Figure 1. According to this model, the word is parsed into its component morphemes, which activate their corresponding logogens. Under the decomposition-first hypothesis it is assumed that these logogens are interconnected, so that it is possible to check for an illegal combination; under the decomposition-second hypothesis the interconnections are assumed to be active for the corresponding units in the cognitive system. It should be noted that for our purposes it is not necessary to be able to distinguish between the decomposition-first and the decomposition-second model, since our argument will mainly be concerned with the need for postulating visual recognition devices for affixes and will not address the issue of the actual ordering of the processing stages. From the input logogens the information

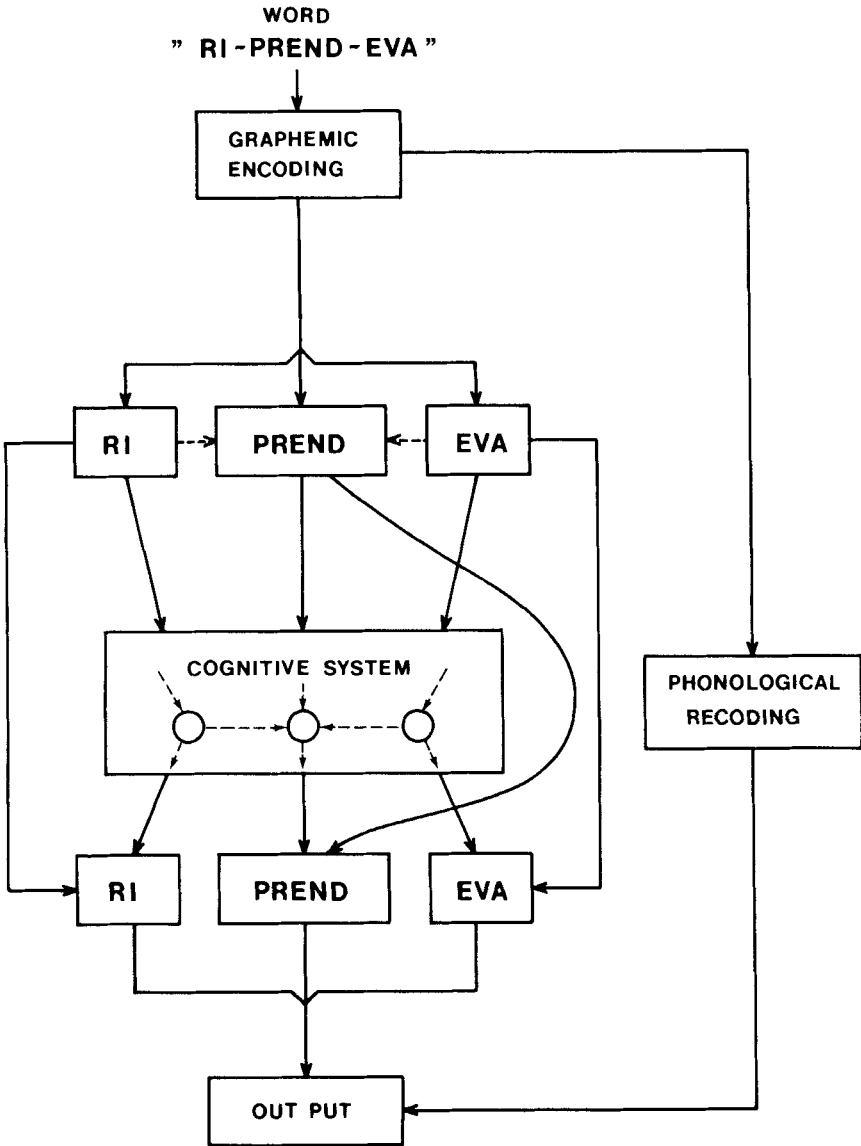


Figure 1. Modified logogen model with visual recognition devices for affixes for the processing of affixed items.

is sent to the cognitive system, even if the system provides for direct connections with the output logogens. Of course, if any part resulting from the application of the parsing mechanism is not a valid root-morpheme or affix of the language, no logogen will exist for it, and therefore it will be processed through the non-lexical route.

The evidence for recognition devices for affixes comes from the following findings obtained in our investigations with Leonardo:

1. If an affix is embedded in a non-word, it has a high probability of being read correctly with respect to a control non-word (tasks 3 and 4). As Leonardo is supposed to have the non-lexical route to phonology destroyed or at least greatly impaired, this means that some visual recognition devices are activated for correctly reading a significant proportion of affixes. So if a composite non-word such as *ri/bit/are* (real affixes, false root morpheme) is presented for reading aloud, the stimulus is decomposed into affixes and pseudo-morpheme. Affixes are read through the activation of specialized visual input logogens, while the non-root morpheme is processed through the phonological recoding stage. The operation of the former process will be successful, while that of the latter—because of its impairment—will most probably give rise to an error.

2. Prefixed non-words such as *ri/leone* [*re/lion*], where both *ri* and *leone* are legal, are read better than control non-words derived by changing a letter both in the prefix and in the word (task 5).

The connection between affix recognizers and the cognitive system must be active in Leonardo, since when an affix is presented visually and he is required to recognize its “meaning” among three alternatives, his accuracy is high while accuracy to control non-words is at chance level (task 6). This result is in accordance with the model, since non-words do not have visual recognition devices and the only possible route through which they can be processed is the phonological one, which is impaired.

Before discussing how the lexical decision data can be accounted for by the modified model presented here, we should consider some reading data reported by Funnell (1983) which seem incompatible with the model. Funnell’s patient W.B., a phonological dyslexic, was in fact unable to read inappropriately suffixed words and isolated suffixes. *Prima facie*, this seems strong evidence against the view that suffixes are present in the visual input logogen system, and Funnell explicitly states this.

It seems to us that there are two—not necessarily mutually exclusive—ways in which the inconsistency between Funnell’s data and ours could be resolved. One way would be to maintain both Funnell’s and our own proposals and to assume differences across languages. Thus, it may be that the Italian reading system is different from the English with respect to affix processing, given the relative importance of inflections in the two languages. The second way of resolving the inconsistency would be to assume differences across patients. According to this view, Funnell’s proposal should be abandoned, and it should be assumed that affixes are in fact present in the visual input logogen system. W.B.’s pattern of results could then be explained by assuming that his suffix input recognizers are impaired, so that no information collected from the stimulus is sufficient for the logogen to reach threshold. This may explain why he cannot read isolated suffixes. However, when a root-morpheme and an affix are

presented together, the model requires that a check is made to determine whether the root-morpheme and the affix constitute a legal sequence. This further information may sometimes be sufficient to activate the affix logogens, so that we should expect some correct responses as well as some affix substitution when a root-morpheme and an affix are presented in illegal association.

Inspection of the data reported by Funnell shows two results that seem to be compatible with this prediction. First, while the majority of W.B.'s responses to non-words were omissions, he made 50% suffix substitution errors on a list of 10 "normally" written non-words formed by a root-morpheme and a suffix in illegal association. Second, when shown an isolated printed suffix whilst listening to a spoken root-morpheme, W.B. could say the resulting inflected word. Of course, these data are only suggestive, and more evidence is needed to be able to dismiss one or the other of the two hypotheses. Surely, if we were able to find an English reader who could read isolated suffixes, the difference-across-languages hypothesis should be abandoned.

The data from the lexical decision tests are also accounted for by the proposed model. In fact, if a non-word is derived by changing a letter in the suffix, accuracy is fairly good—at least as good as accuracy with non-words derived by changing a letter in the morpheme. Moreover, accuracy, at least with verbs, is higher with suffix changing than root morpheme changing. According to Patterson (1980), in the presence of a total abolition of the non-lexical route there should be chance performance, since the difference between words and non-words is in the suffix, which is assumed to be processed by the impaired phonological route. The model proposed here, however, correctly predicts good performance for the task in question, since suffixes also have their visual recognizers.

The varieties of errors produced by Leonardo and summarized in Table I could be explained by the proposed modified logogen model invoking two principles. The first of these states (a) that affix and root-morpheme substitution can both occur, and (b) that their occurrence is due to the activation of inappropriate logogens, possibly because of inaccuracies at the stage of visual analysis. The second principle states that deletion and addition can occur, in Italian, only for prefixed words. This is because prefixes, unlike suffixes and root-morphemes, can have empty forms, and thus only deletion of suffixes and of root-morphemes would result in a response that would be a non-word.

The problem of why a prefix present in the stimulus is sometimes deleted or a prefix not present in the stimulus is sometimes added still remains, of course. At present, we do not have an answer, other than assuming a different strength for root-morpheme recognizers and affix recognizers. On this issue, some evidence is also available, which seems to imply that recognizers for root-morphemes and affixes do not play an equal

role in lexical decision. If a non-word has a real root-morpheme and a non-suffix, lexical decision is more accurate (verbs $d' = 4.35$; nouns $d' = 1.20$) than with a non-word composed of a non-“root-morpheme” and a real suffix (verbs $d' = 2.87$; nouns $d' = 1.05$). It seems, then, that the response is weighted more in respect of the root-morpheme recognizer than of the suffix one.

REFERENCES

- Bulmer, M. G. (1967). *Principles of statistics*. Edinburgh: Oliver and Boyd.
- Coltheart, M., Patterson, K. and Marshall, J. C. (Eds.) (1980). *Deep dyslexia*. London: Routledge and Kegan Paul.
- Funnell, E. (1983). Phonological processes in reading: New evidence from acquired dyslexia. *British Journal of Psychology*, 74, 159–180.
- Manelis, L. and Tharp, D. A. (1977). The processing of affixed words. *Memory and Cognition*, 5, 690–695.
- Morton, J. and Patterson, K. (1980). A new attempt at an interpretation or an attempt at a new interpretation. In M. Coltheart, K. Patterson and J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge and Kegan Paul.
- Murrell, G. A. and Morton, J. (1974). Word recognition and morphemic structure. *Journal of Experimental Psychology*, 102, 963–968.
- Patterson, K. (1980). Derivational errors. In M. Coltheart, K. Patterson and J. C. Marshall (Eds.), *Deep dyslexia*. London: Routledge and Kegan Paul.
- Patterson, K. (1982). The relation between reading and phonological coding: Further neuropsychological observations. In A. W. Ellis (Ed.), *Normality and pathology in cognitive functioning*. London: Academic Press.
- Rubin, G. S., Becker, C. A. and Freeman, R. H. (1979). Morphological structure and its effect on visual word recognition. *Journal of Verbal Learning and Verbal Behavior*, 18, 757–767.
- Taft, M. (1979). Recognition of affixed words and the word frequency effect. *Memory and Cognition*, 7, 263–272.
- Taft, M. (1981). Prefix stripping revisited. *Journal of Verbal Learning and Verbal Behavior*, 20, 289–297.
- Taft, M. and Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, 14, 638–647.

Revised manuscript received 8 November 1983