Prefix Stripping Revisited

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Rubin, Becker, and Freeman (Journal of Verbal Learning and Verbal Behavior, 1979, 18, 757–767) have recently claimed that prefixed words are only recognized via a prefix-stripping procedure in certain experiment-specific circumstances. The experiments reported in the present study, however, provide evidence for the prefix-stripping procedure when no strategies are likely. Explanations for the discrepancy between the present results and those of Rubin et al. are discussed.

In 1975 Taft and Forster put forward a model for the visual recognition of prefixed words. According to this model, a prefixed word is stored in the lexicon as a representation of its stem, with information stored within this lexical entry about what can combine with the stem to form a word. Thus when a prefixed word is to be recognized, it is firstly decomposed into its prefix and stem, and lexical access then proceeds on the basis of the stem only. Once the appropriate lexical entry is located on this basis, the prefix information stored within this lexical entry can be consulted and the word can thus be recognized.

Recently, however, both Stanners, Neiser, and Painton (1979) and Rubin, Becker, and Freeman (1979) have reexamined the Taft and Forster model. The first paper suggests that prefixed words are represented both as stems and as whole words, while the second claims that the results on which Taft and Forster base their model are strategy effects specific to the experimental setting. The aim of the present paper is to examine these criticisms and attempt to answer them.

THE CRITICISMS MADE BY STANNERS ET AL.

Stanners et al. observed that the lexical decision time to a prefixed word (e.g., RETRIEVE) was facilitated when this word was preceded by a lexical decision response to the stem of that word (TRIEVE) along with another word with the same prefix (REMIT). This facilitation, however, was not as great as when the prefixed word was repeated exactly (i.e., RETRIEVE followed by RETRIEVE). The interpretation of these results given by Stanners et al. is that prefixed words are stored both as whole words and as stems, with interconnections between these two entries. The presentation of the item TRIEVE partly activates the lexical entry RETRIEVE and this leads to a certain amount of facilitation of the response time to the item RETRIEVE. If RETRIEVE were represented solely as TRIEVE, Stanners et al. claim that the combined effect of TRIEVE and REMIT should be exactly the same as that of RETRIEVE in facilitating response times to RETRIEVE.

FLAWS IN THE STANNERS ET AL. CRITICISMS

According to Taft and Forster the word RETRIEVE is recognized as a word by stripping off the RE, locating the lexical entry TRIEVE, and finally determining that RE combines with TRIEVE to form a word. Thus there are three stages in the recognition process. When the item RETRIEVE is to be recognized as a word, and
it has been preceded by TRIEVE and REMIT, only the first two of those stages has been facilitated: RE has been stripped from a word, and TRIEVE has been accessed. The decision that RE combines with TRIEVE has not been made before in the experiment and therefore there should be less facilitation on lexical decision times here than when all three stages have already been passed through, namely, when RETRIEVE has been presented earlier. Therefore, the results obtained by Stanners et al. can easily be handled by the Taft and Forster model. This explanation can also account for the further finding of Stanners et al. that a stem word (e.g., HAPPY) is facilitated to the same degree by a preceding prefixed word containing that stem (e.g., UNHAPPY) as it is by the stem word itself (HAPPY). The word UNHAPPY passes through the three stages of recognition outlined above while the word HAPPY passes through just one of them (i.e., locating the lexical entry HAPPY). This one stage was passed through previously both when the preceding word was HAPPY and when it was UNHAPPY, and so the two produce equivalent facilitation.

The experiments performed by Stanners et al., then, do not create a problem for the Taft and Forster model whereby prefixed words are represented solely by their stems in the lexicon. The notion that whole words as well as stems are stored in the lexicon is an unnecessary elaboration of the model on the basis of these experiments.

Rubin, Becker, and Freeman, however, present a different kind of evidence which appears to lead to the same conclusion as that of Stanners et al., that prefixed words are stored both as stems and as whole words. Rubin et al. go further though, and say that the stem representation is only accessed in certain specific circumstances.

THE CRITICISMS MADE BY RUBIN ET AL.

If prefixes were stripped from stems prior to lexical access, as the Taft and Forster model claims, then it would follow that parts of nonprefixed words that look like prefixes but are not would also be stripped off indiscriminately. Thus an attempt would be made to recognize the word RELISH by looking for LISH in the lexicon since RE is a putative prefix. However RELISH is not a prefixed word and therefore its lexical representation would not be LISH, but rather RELISH (or, more exactly, REL. See Taft & Forster, 1976; Taft, 1979a). Therefore the recognition of RELISH, a pseudoprefixed word, would be delayed by its misleading decomposition into "prefix" and "stem." Rubin et al. demonstrate that lexical decision times to pseudoprefixed words are indeed longer than those to genuinely prefixed words (e.g., REPAY), where lexical access can be achieved successfully through the stem (PAY). This finding is true, however, only when all the nonwords in the experiment are also prefixed (e.g., RETEXT). When the nonwords are all nonprefixed (e.g., RATISFY), the difference between prefixed and pseudoprefixed words disappears. From this result, Rubin et al. claim that prefix stripping is not a necessary part of word recognition and is only observed when there are many prefixed items in the experiment. Therefore, they claim that Taft and Forster's results are strategy effects.

What is meant by strategy here? Taft and Forster ran three experiments, two of which contained no prefixed items at all and are therefore not open to the criticism of Rubin et al. For example, from the finding that stems like VIVE took longer to classify as nonwords than pseudostems like LISH it was concluded that stems are represented in the lexicon. This, however, does not preclude the possibility that REVIVE is stored both as a whole word and as its stem (as Stanners et al. suggest). Thus what Rubin et al. must mean by a strategy effect is that normal recognition of REVIVE uses the whole word representation of REVIVE, but when there are a lot of prefixed items in the experiment the alternative route to recognition is used, namely, through the stem VIVE.
There are two major flaws in the criticisms made by Rubin et al., one logical and one empirical.

First, for subjects to adopt a strategy of prefix stripping when the nonwords are all prefixed seems to be counterproductive. All it would achieve would be to make the pseudoprefixed words (e.g., RELISH) harder to recognize. Prefix stripping would not be an aid to nonword classification either, since if RETEXT did exist in English it would be represented as the whole item RETEXT (as well as TEXT). Hence, once lexical access failed for the representation RETEXT, this should provide sufficient information to ascertain that RETEXT is a nonword, and prefix stripping should be unnecessary.

If a strategy effect is logically unlikely, then how can one explain the experimental results of Rubin et al. The answer to this lies in the strong possibility that the failure to find a prefixed/pseudoprefixed difference when no prefixed nonwords were used was itself a strategy effect of a different kind. In this noncontext condition, subjects could be sure than when the item they were presented with began with letters that formed a prefix (as with REPLAY and RELISH) the item would always be a word. In no cases were such items nonwords. There could therefore have been a very strong bias to respond "yes, it is a word" before the full lexical access procedure had been completed, namely, once the initial letters had been recognized as forming a prefix. If such a strategy were adopted, one might expect to find that the prefixed words (as well as the pseudoprefixed words) have faster reaction times in the noncontext condition than in the context condition. The experiments to be reported here attempt to demonstrate that prefix stripping is not a special strategy, but rather, is the normal method of recognizing prefixed words. This claim can be made if it can be demonstrated that the processing of pseudoprefixed words is retarded even when no strategies are possible.

**Experiment 1**

The purpose of the first experiment was to confirm the basic finding that pseudoprefixed words take longer to recognize than prefixed words, at least in the context of prefixed nonwords. In addition though, a difference was made in the procedure for selecting prefixed words, since there was a problem with the prefixed words used by Rubin et al. The ones chosen by Rubin et al. were all cases where the stems were words in their own right (e.g., DEVOID, MISPLACE) and it is possible that lexical decision times to such items are influenced by the frequency of their word stems. Taft (1979b) has demonstrated that stem frequency does seem to contribute to response times by showing, for example, that the high frequency of the word APPROACH makes REPROACH easier to recognize than DISSUADE, where DISSUADE has the same frequency as REPROACH, but PERSUADE is less frequent than APPROACH. That is, PROACH is a more common stem than SUADE and this influences response times to any word containing it as a stem.

It is therefore possible that the difference Rubin et al. observe is not solely a result of the mistaken decomposition of pseudoprefixed words, but rather, of a boost in the frequency of the prefixed words from their stem frequencies, or a result of both. If the frequency explanation is true, it must mean that prefixed words and the stems of such words are stored together in the lexicon. It is difficult to conceive how any special
strategy, (adopted when the nonwords of the experiment are manipulated), could alter the frequency effect, since the effect arises from the way the words are stored rather than from some modifiable retrieval mechanism. Thus for the arguments of Rubin et al. about strategies to hold, the difference between prefixed and pseudoprefixed words must be the result of an inadvertent stripping of pseudoprefixes in the retrieval process.

In the present experiment, prefixed words were selected in such a way that stem frequency could not play a role. The words selected were all cases whose stem only ever occurred in that particular word. For example, the stem of the prefixed word ADVANCE is VANCE and, since it only occurs in the word ADVANCE, it cannot bias the frequency of that word. A further modification to item selection was made in this experiment. Prefixed and pseudoprefixed words were designed in pairs matched on frequency and approximate length as well as on stress pattern. If the stress fell on the second syllable of a prefixed word (e.g., ADVANCE) then the stress fell on the second syllable of its matching pseudoprefixed word (UNIQUE). Similarly, if the stress fell on the first syllable of the prefixed word (e.g., REPLICA) then the same was true of the matching pseudoprefixed word (PRECIPICE). The decision whether a word was prefixed or not was based upon ratings given by ten independent judges.

Experiment I therefore was an attempt to replicate the Rubin et al. finding of a prefixed/pseudoprefixed word difference, using a more stringent set of criteria for designing the items in order to be sure that any such difference was a result of a disruption in the retrieval stage of lexical access.

Method

Materials. Items for the experiment were selected from a corpus of words which had been rated by ten independent judges on "prefixedness." The words in this corpus all began with letters that formed a prefix and in every case the remaining "stem" was unique to that word. Raters were asked to say which of the words they considered to be genuinely prefixed. This task proved quite difficult, since the usual criterion for deciding whether a word is prefixed or not is to see if other words exist that contain the same stem. Since items were designed specifically to have unique "stems," this criterion could not be used. Instead, raters seemed to decide whether the "prefix" contributed any meaning to the word. For example, REPLICA would have been considered as prefixed since RE conveys some of the concept of duplication.

From this corpus, 25 prefixed words and 25 pseudoprefixed words were selected. These are listed in the appendix. A word was taken as being a prefixed word if more than 5 of the 10 judges rated it as such, and as being a pseudoprefixed word if none or only one of the judges rated it as prefixed. The items were designed in pairs so that for each prefixed word there was a pseudoprefixed word matched on frequency, approximate length, and on stress pattern. Since the selection criteria were so limiting, many of the words selected were of rather low frequency and it is at these low levels that frequency listings (like that of Kučera & Francis, 1967) can be grossly affected by sampling errors. For this reason, frequency matching in this experiment was based on both the Kučera and Francis word count and a second frequency listing, that of Carroll, Davies, and Richman (1971). The 50 word items so selected were semirandomly presented together with 50 nonword items all of which began with letters that formed a prefix (e.g., ENSTROPE, REGORA). In addition, there were 12 practice items; 6 prefixed and pseudoprefixed words and 6 prefixed nonwords.

Procedure. A lexical decision task was employed whereby subjects were required to classify items as word or nonword. This was achieved by pressing a button marked
as either "word" or "nonword." Items were presented on a video display unit which was controlled by a PDP-11/10 computer, each item appearing for a duration of 500 msec. Items were presented in a different order for each subject. Subjects were instructed to respond as quickly but as accurately as they could. Item display was self-paced, with subjects pressing a foot switch each time they wished to receive the next item. Response time was measured from the time the stimulus item appeared on the screen to the time the subject pressed the response button. There were 25 subjects tested.

Results and Discussion

In order to minimize the effects of isolated trials with exceptionally long or short latencies, cutoff points were established two standard deviation units above and below the mean for each subject. Any outlying values were then set equal to the appropriate cutoff value. Mean lexical decision times were determined for the two conditions and these are presented in Table 1, along with percentage error rates.

An analysis of these data revealed a significant difference both for reaction times, $\text{min } F'(1,41) = 4.14, p < .05$, and for errors, $\text{min } F'(1,31) = 10.84, p < .01$. It is therefore apparent that pseudoprefixed words were harder to recognize than prefixed words as reflected by both the speed and the accuracy with which subjects could classify them as words. This result confirms the Rubin et al. finding using a context of prefixed nonwords, and further suggests that the explanation for the difference is not (solely) that stem frequency boosts the frequency of prefixed words. Rather, it seems that the letters that form a prefix are stripped off the pseudoprefixed words indiscriminately and this is inappropriate since such words are stored as whole units rather than as stems. Therefore, as Rubin et al. suggest also, it appears that prefix stripping occurs in the recognition of prefixed words, at least when the nonwords in the experiment are also prefixed.

Experiment 2

Although there is much support for the notion that prefixed words are decomposed into prefix and stem, Rubin et al. claim that such a process is a special strategy adopted when the majority of items in the experiment are prefixed and that it is not the normal method of recognition. In order to examine this view, one can use a technique whereby there is a measure of word recognition difficulty without the presence of any nonwords. This technique is the use of naming time. Forster and Chambers (1973) have demonstrated that the time taken to name an item, that is, to initiate its pronunciation, is influenced by the two main factors that also influence lexical decision time, namely, frequency and lexical status (word or nonword). This implies that a word is pronounced after its lexical entry has been accessed since pronunciation time seems to reflect access time. If this is so, then the difficulty encountered with pseudoprefixed words in the lexical decision task should also be apparent in the naming task.

In Experiment 2 only prefixed words and pseudoprefixed words were used. Since half of the words were prefixed and the other half were not prefixed there would seem to be no reason for subjects to adopt a prefix-stripping strategy in preference to a whole word access approach, if both approaches are available. The method of lexical access used in this situation would have to be the normally preferred method, which, according to Rubin et al., should be the whole word approach whereby prefixed

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example</th>
<th>RT</th>
<th>Error</th>
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<tbody>
<tr>
<td>Prefixed</td>
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<tr>
<td>Pseudoprefixed</td>
<td>PRECIPICE</td>
<td>641</td>
<td>16.3</td>
</tr>
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</table>
and pseudoprefixed words are treated in the same way.

**Method**

*Procedure.* The same words that were used in the first experiment were used here. This time, however, the dependent variable was naming time rather than lexical decision time, and no nonwords were used.

The experimental setup was the same as in the first experiment, but rather than pressing buttons, subjects were required to say the word that they saw as quickly as they could into a microphone. Response times were measured from the onset of the stimulus word until the timing mechanism detected the naming response.

Since it could not always be guaranteed that the naming response could be detected by the timing mechanism at the same point in every word, a naming control task was performed after each subject completed the naming task. In this naming control task, subjects were presented with all the items again for one second each, and this time they began pronouncing the word 500 msec after the offset of each word, when a row of equal signs appeared. The time taken for the timing mechanism to detect this vocal sound (articulation time) began when the equal signs appeared. At that point, the subjects knew what the word was and how it should be pronounced. In this way a measurement of articulation time could be obtained without any influence of accessing difficulty. In the analysis of the subject data the mean naming control time for each condition was subtracted from the mean naming time for each condition, while in the item analysis, the mean naming control time for each item was subtracted from the mean naming time for each item.

Ten subjects were run in this experiment.

**Results and Discussion**

Two types of responses were not included in the naming time analysis. One was where the subject did not pronounce the word correctly, while the other was where the timing mechanism was never triggered by the vocal response. Only the former were included in the error analysis.

Table 2 provided the mean naming time for each condition with the naming control time subtracted from it. The difference between pseudoprefixed and prefixed words was found to be significant for both RT, \( \min F'(1,33) = 9.51, p < .01 \), and errors, \( \min F'(1,25) = 7.05, p < .02 \).

It is therefore clear that pseudoprefixed words are incorrectly treated as prefixed words even when there are as many pseudoprefixed items as prefixed items in the experiment, and there are no nonwords. It appears that naming time reflects the same access difficulties that lexical decision time reveals. Such a finding greatly weakens the Rubin et al. notion that prefix stripping is a strategy that is only adopted when there is a preponderance of prefixed items in the experiment. Perhaps though, Rubin et al. might argue that having half of the items as prefixed is sufficient to induce the prefix-stripping strategy. Although this idea seems unlikely in that all it would achieve would be a slowing down of responses to pseudoprefixed words, a third experiment was performed to guard against any such criticism.

**Experiment 3**

In this experiment no prefixed items were included. If pseudoprefixed words are mistakenly treated as prefixed words and this delays lexical access of such words, then they should show longer response times than nonprefixed words which can be accessed as whole units immediately. Hence, in a naming task with no nonwords
and no prefixed words, it should be found that pseudoprefixed words (e.g., UNIQUE, PRECIPICE) take longer to start saying than nonprefixed words (e.g., CREATE, PINNACLE). Such a finding could not be explained away as a strategy effect since there are no prefixed items in the experiment to bias subjects toward any prefix-stripping strategy.

**Method**

**Materials.** The same 25 pseudoprefixed words that were used in the first two experiments were used in this experiment. For each of these pseudoprefixed words there was a nonprefixed word matched on frequency based on the two word counts (Kučera & Francis and Carroll et al.), approximate length, and also stress pattern. Items are listed in the appendix.

**Procedure.** The procedure was exactly the same as for Experiment 2. Again ten subjects were run.

**Results and Discussion**

It can be seen from Table 3 that the pseudoprefixed words took longer to name than the nonprefixed words and this proved to be significant, \( \min F'(1,31) = 7.27, p < .02 \). The error difference was significant on both the subject and the item analysis individually, \( F_1(1,9) = 8.31, p < .02; F_2(1,24) = 4.99, p < .05 \), respectively, but not on the \( \min F' \) analysis, \( \min F'(1,31) = 3.08, p > .05 \).

From these results it is evident that pseudoprefixed words are not accessed immediately as whole words but are mistakenly treated as prefixed words even when there are no genuinely prefixed words in the experiment. Therefore it appears that the failure of Rubin et al. to find a pseudoprefixed word effect in a lexical decision task with nonprefixed nonwords does not reflect the normal reading process as they suggested. Rather, it seems that a special strategy was being used by subjects in those circumstances, namely, that they were responding "it is a word" when the item was found to begin with a putative prefix rather than after the completion of lexical access.

Finally, the apparent difference between the pseudoprefixed words of Experiment 2 and those of Experiment 3 (a 60-msec difference) might seem to be a puzzling result. However, while the Item analysis of the pseudoprefixed words common to both experiments yields a significant RT difference, \( F(1,21) = 8.53, p < .01 \), the Subject analysis is far from significance, \( F(1,18) < 1 \). Such a pattern of results is typical of a between-subjects design where there are one or two subjects in one of the conditions who are particularly slow in responding. These slow responses would systematically increase the means of all items in that condition, leading to a significant Item analysis, but they would not lead to a significant Subject analysis. It therefore seems that the apparent difference between the pseudoprefixed words of Experiment 2 and Experiment 3 is simply an artifact of subject variation.

**General Conclusions**

The finding of a difficulty in pseudoprefixed word recognition in circumstances where no strategies are likely is in itself a boost to the Taft and Forster model of prefix stripping. Pseudoprefixed words would not be mistakenly decomposed if a prefix-stripping procedure did not exist and such a procedure would only exist if genuinely prefixed words were decomposed.

Stanners et al. modification to the model...
seems to be an unnecessary elaboration given the alternative explanation of their results outlined in the introduction. In addition, the stem-frequency effect obtained by Taft, (as outlined in the introduction to Experiment 1), would be difficult for both Stanners et al. and Rubin et al. to handle. For the frequency of the stem of a prefixed word to influence lexical decision times, it would seem necessary that the lexical representation of that word be the stem.

In summary, then, from the finding that pseudoprefixed words are indiscriminately treated as prefixed words, it can be concluded that prefix stripping occurs in word recognition and this, in turn, implies that prefixed words are accessed through a representation of their stem. This is very unlikely to be a task-specific strategy, as Rubin et al. suggest, since the result was obtained in circumstances where strategies would not be available.

APPENDIX

Below are listed the prefixed words and pseudoprefixed words along with their lexical decision time (Experiment 1) and their naming time minus naming control time (Experiment 2).

<table>
<thead>
<tr>
<th>Prefixed words</th>
<th>Expt 1</th>
<th>Expt 2</th>
<th>Pseudo-prefixed words</th>
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<th>Expt 2</th>
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Below are listed each pseudoprefixed word followed by the matching nonprefixed word used in Experiment 3, along with their naming time minus naming control time.

DEVOUT 262, HUMANE 247; ASSASSIN 205, TUITION 303; ENAMEL 232, Moustache 280; DELICIOUS 289, BANANA 165; ENIGMA 370, FIASCO 238; UNANIMOUS 281, FACILITATE 333; DESPAIR 265, GUITAR 233; INSTRUMENT 325, TERRIBLE 188; DELUGE 310, JARGON 202; REGATTA 306, GRAFFITI 266; UNIQUE 284, CREATE 208; DEVIL 211, RIGID 236; DELIRIOUS 244, MUTATION 253; DESTINATION 250, GUARANTEE 159; DISCIPLE 320, CADET 184; ECLIPSE 334, SALUTE 169; INDIGO 344, BUNGALOW 332; PROSAIC 295, BURLESQUE 357; PROMENADE 383, SABOTAGE 260; PREMIUM 390, THERAPY 222; EMBRYO 288, CINNAMON 302; AMIABLE 406, WISTFUL 228; PRECIPICE 330, PINNACLE 243; BENIGN 318, LAMENT 301; PREDATION 371, TABASCO 333.
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