JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR **15**, 607–620 (1976)

Lexical Storage and Retrieval of Polymorphemic and Polysyllabic Words

MARCUS TAFT AND KENNETH I. FORSTER

Monash University

Five experiments are described which examine how polysyllabic words (e.g., DAYDREAM, ATHLETE) are stored and retrieved from lexical memory. The first four experiments look at interference effects caused by the accessing of inappropriate lexical entries. It is found that compound nonwords whose first constituent is a word (e.g., DUSTWORTH, FOOTMILGE) take longer to classify as nonwords than compound nonwords whose first constituent is not a word (e.g., TROWBREAK, MOWDFLISK). Moreover, the presence of a word in the second constituent position appears to be irrelevant. These effects hold even when the boundary between constituents is unclear on an orthographic basis (e.g., TRUCERIN). It is also argued that first syllables, as opposed to last syllables, have independent status in the lexicon since nonword first syllables (e.g., ATH) show interference effects, while last syllables (e.g., CULE) do not. The fifth experiment reveals that the frequency of the first constituent of a compound word influences classification times. The results point to the conclusion that polysyllabic words, regardless of whether they are polymorphemic or monomorphemic, are accessed via their first syllable.

It is commonly accepted that a written word is recognized and comprehended when some coded version of the sensory representation of that word is found to match with a memory representation in the reader's long-term word store, or lexicon (Norman, 1970; Rubenstein, Garfield, & Millikan, 1970; Forster & Chambers, 1973). However, it has been shown that it is not necessary for this matching procedure to be based on the sensory and lexical representations of the *complete* word. Taft and Forster (1975) have produced evidence to suggest that recognition of a prefixed word (e.g., REJUVENATE) entails the decomposition of that word into its constituent morphemes, namely its prefix (RE) and its stem (JUVENATE), since the stem, not the word as a whole, is apparently the target for lexical search. There is also evidence to indicate that inflected words, such as CATS or FALLING are recognized by accessing the lexical representations of their stems, that is, CAT and FALL (Gibson & Guinet, 1971; Kintsch, 1972; Snodgrass & Jarvella, 1972; Murrell & Morton, 1974; Jarvella & Snodgrass, 1974).

The authors are grateful to Donald M. Thomson for his helpful comments regarding this paper. Requests for reprints should be addressed to Marcus Taft, Department of Psychology, Monash University, Clayton, Victoria 3168, Australia.

If it is true that a polymorphemic word is accessed on the basis of its stem, then what happens in a case where the polymorphemic word is effectively composed of two stems, as in the case of compound words like DAYDREAM and MILESTONE? In such a case, is a lexical search carried out for *both* constituent morphemes, or is there a search for just *one* of the morphemes? If the latter is true, which of the morphemes is used—the first or the last? Another possible alternative is that no morphological decomposition takes place at all, so that a compound word is actually stored and retrieved from the lexicon as a whole word. Experiment I was designed to investigate these questions.

EXPERIMENT I

It has been demonstrated by Taft and Forster (1975) that a nonword which has the morphological structure of a prefix plus a stem takes longer to classify as a nonword if the stem has lexical status (e.g., DEJUVENATE) compared with items where the stem does not have lexical status (e.g., DEPERTOIRE). In both cases, the prefix is assumed to be stripped off and a search for the stem is undertaken; however, in the former case, the search is interrupted by the finding of a lexical entry (JUVENATE, which is required for the recognition of the word REJUVENATE) and this slows up the classification response.

The present experiment is designed on similar lines; it is assumed that classification times for nonwords will be lengthened if the lexical search is interrupted by the discovery of an entry that ultimately turns out to be inappropriate. If compound nonwords (e.g., DUSTWORTH, MOWDFLISK) are classified as nonwords on the basis of their constituent units rather than on the basis of the item as a whole, then those nonwords whose constituent units have lexical status (DUSTWORTH) would be associated with longer classification times than those nonwords whose constituent units have no lexical status (MOWDFLISK).

If classification time is based on lexical search for only the first constituent unit, then the lexical status of the second constituent would be irrelevant. Thus, nonwords like FOOTMILGE would take longer to classify than nonwords like TROWBREAK. Conversely, if classification time is based on lexical search for only the second constituent unit, then TROWBREAK would take longer to classify than FOOTMILGE. If both constituent units were important, then there would be no differences between FOOTMILGE and TROWBREAK.

Method

Materials. Four different nonword conditions were set up with 10 items in each: nonwords constructed from two unrelated words (WW), that is, DUSTWORTH, BRIEFTAX; nonwords constructed from a word followed by a nonword (WN), that is, FOOTMILGE, CLEANMIP; nonwords constructed from a nonword followed by a word (NW), that is, TROWBREAK, THERNLOW; and nonwords constructed from two nonwords (NN), that is, MOWDFLISK, SPILKWUT. Constituent units were matched across the four item conditions for length and, where they were words, for frequency of usage according to the Kučera–Francis word count (Kučera & Francis, 1967).

The 40 nonword items (presented in the Appendix) were randomly interspersed with 40 distractor word items which were constructed in the same way as the nonwords, that is, from two unrelated words (e.g., BLACKMAIL, NICKNAME); from a word followed by a nonword (e.g., SANDWICH, NEIGHBOR); from a nonword followed by a word (e.g., HENCHMAN, STALWART); and from two nonwords (e.g., SHRAPNEL, WALRUS).

To eliminate any doubts as to what the constituent units were for any particular item, the constituent boundary of every compound nonword (and compound word) was indicated by a letter pair that was of zero, or at least very low, probability of occurrence within a syllable, for example, the TM of FOOTMILGE. Thus, FOOTMILGE has to be analyzed as a word plus a nonword, that is, FOOT + MILGE, since both FOO + TMILGE and FOOTM + ILGE involve orthographic "illegalities."

Procedure. The procedure was the same for all experiments reported in this paper. Items were typed on cards and presented by means of a two-field tachistoscope for 500 msec. The subject held a "Yes" response button in one hand and a "No" response button in the other and was instructed to press the former if the stimulus item was a valid English word and the latter if the stimulus item was not a word. Subjects were told to respond as quickly but as accurately as possible. The intertrial interval was approximately 5 sec, with the experimenter saying "ready" prior to the presentation of each stimulus item. The items were presented in a different order for each subject. Twelve practice items were also presented. Fifteen paid subjects were used in each experiment.

In this and in all subsequent experiments, the effects of isolated trials with exceptionally long or short latencies were minimized by establishing a cutoff point two standard deviation units away from the means for each subject and by setting any outlying values equal to the cutoff. Trials on which an error was made were omitted.

Results and Discussion

Mean reaction times and percentage error rates over all subjects for each of the nonword conditions are given in Table 1.

TABLE 1

MEAN CLASSIFICATION TIMES (MILLISECONDS), STANDARD ERRORS, AND PERCENTAGE ERROR RATES FOR WW, WN, NW, AND NN NONWORDS (EXPERIMENT I)[a]

Condition	Example	RT[b]	*SE*	Percentage error
WW	DUSTWORTH	758	37	9
WN	FOOTMILGE	765	45	2
NW	TROWBREAK	682	32	5
NN	MOWDFLISK	677	28	4

[a] Standard errors are based on between-subjects variability.
[b] Reaction time.

A one-way analysis of variance with repeated measures revealed an overall difference in reaction time across the four conditions, *min* $F'(3, 18) = 6.48$, $p < .01$. Looking at individual comparisons, it was found that both WW nonwords (DUSTWORTH) and WN nonwords (FOOTMILGE) were associated with longer reaction times than NW nonwords (TROWBREAK), *min* $F'(1, 15) = 9.59$, $p < .01$ and *min* $F'(1, 17) = 7.57$, $p < .02$, respectively, and also longer reaction times than NN nonwords (MOWDFLISK), *min* $F'(1, 19) = 12.65$, $p < .01$ and *min* $F'(1, 23) = 8.31$, $p < .01$, respectively. There was no difference between WW and WN nonwords, *min* $F' < 1$, with neither the subject analysis, $F_1(1, 14) = 0.23$, $p > .05$, nor the item analysis, $F_2(1, 9) = 0.41$, $p > .05$, being significant. Finally, NW and NN nonwords did not differ, *min* $F' < 1$, with neither the subject nor item analyses being significant, $F_1(1, 14) = 0.18$, $p > .05$ and $F_2(1, 9) = 0.07$, $p > .05$.

Although more errors were made in the WW condition than in any other, an analysis of the errors across the four conditions revealed no overall significant difference, *min* $F'(3, 20) = 1.27$, $p > .05$.

It is evident that some sort of morphological analysis must be involved in the processing of compound items, since the lexical status of the constituent units of compound nonwords is able to influence classification times. In point of fact, it is clear that it is only the lexical status of the first constituent that is important in this regard; whether or not the second constituent unit is a word appears to be irrelevant to the speed of the classification response. This conclusion is based on two results. First, the only conditions showing longer response times than the NN control condition were those in which the first constituent was a word (i.e., WN and WW). Second, no extra interference was produced when the second constituent was a word (i.e., WW was no slower than WN).

On the basis of these results, the following model of compound word recognition can be formulated. The item is first decomposed into its constituent units (Experiment IV will examine how this is achieved) and a lexical search is undertaken for the first constituent. When the appropriate lexical entry is found, information within the entry stipulates whether or not the second consitituent can go together with the first to form a valid English word. Only if the second constituent is listed in this way will the item be recognized as a word.

In compound words, such as DAYDREAM, the first constituent (DAY) is both a morpheme and a syllable, and thus the results of this experiment are ambiguous as to whether storage is in terms of morphemes or syllables. To differentiate the two, an examination must be made of words that are polysyllabic but monomorphemic, like PLATFORM, ATHLETE, and TADPOLE. If storage is in terms of morphemes, then these items should be stored as whole entities. However, if it is the first syllable that is of importance, then the target of the lexical search for the above items would be PLAT, ATH, and TAD. Hence, these nonwords would have lexical status in a similar fashion to that postulated by Taft and Forster (1975) for nonword stems of prefixed words like JUVENATE, WHELM, and FECT. Experiment II was designed to examine this possibility.

Experiment II

Using similar reasoning to that of Taft and Forster (1975), it can be argued that, if polysyllabic words are represented by their first syllable in the lexicon, then items such as PLAT, ATH, and TAD should take longer to classify as nonwords than items such as PREN, ARN, and GED, which are not first syllables of words. To ensure that any effect obtained was a result of the fact that PLAT is a syllable and not merely the first part of a word, a third type of nonword was included in this experiment. These nonwords also were the first parts of real words, but were not themselves first syllables (e.g., BROT from BROTHER, AWF from AWFUL, and FAW from FAWN).

The prediction, then, is that nonwords like PLAT (Condition 1) should take longer to classify than nonwords such as BROT (Condition 2) and PREN (Condition 3). A search for PLAT will prove successful and it can only be classified as a nonword after information in the lexical entry is found which indicates that it cannot be a word on its own. Before the "No" decision can be made, though, there must be a further search, since it still could be that PLAT is a word. Consider, for example, the word NEIGH. A search for this word might first encounter the lexical entry NEIGH which is stored for the purposes of recognizing the word NEIGHBOR. An error in classification would obviously occur if NEIGH were classified as a nonword simply because the item that was accessed could not stand as a free morpheme. A further search would be necessary in order to find the correct lexical entry for NEIGH. Such a situation would only occur if the nonword entry NEIGH (i.e., the first syllable of NEIGHBOR) was accessed before the word entry for NEIGH. On the assumption that the order of access is controlled by word frequency (Rubenstein, Garfield, & Millikan, 1970; Taft & Forster, 1975; Forster & Bednall, 1976), one would have to predict that delay in the recognition of NEIGH as a word would only occur if NEIGHBOR has a higher frequency than NEIGH, and this is, in fact, so: The frequency of NEIGHBOR in the Kučera–Francis count is 14 and the frequency of NEIGH is zero.

This argument suggests a set of predictions for word items which parallels that for nonword items. That is, words which are also the first syllables of other, more frequent words (Condition 4), that is, NEIGH (from NEIGHBOR), BIB (from BIBLE), MUFF (from MUFFLE), should take longer to recognize than words which are the first part of, but not the first syllable of, other more frequent words (Condition 5), that is, SHREW (from SHREWD), FIR (from FIRST), DIAL (from DIALECT), as well as words which do not even constitute the first part of a word (Condition 6), that is, SCOFF, NUN, ROMP.

Method

Materials. Twenty Condition 1 nonwords were constructed from polysyllabic words by removing the last syllables of these words (e.g., PLAT from PLATFORM). Condition 2 nonwords were obtained by removing the last letters of words which were matched for frequency with the words from which Condition 1 nonwords were obtained. In Condition

2, however, the removal of letters was not at a syllable boundary (e.g., BROT from BROTHER). Condition 3 nonwords were not the first parts of any English words (e.g., PREN). Length was matched across conditions.

Each of the word conditions contained 15 items. There were three word conditions constructed in the same way as the three nonword conditions except that the items were words and were matched across conditions for their frequency of occurrence. In both Conditions 4 and 5, the words from which the experimental items were constructed were always more frequent than the experimental items themselves, that is, NEIGH from NEIGHBOR (Condition 4), SHREW from SHREWD (Condition 5). Condition 6 consisted of words which were not part of any other word (e.g., SCOFF). All items are presented in the Appendix.

Results and Discussion

Mean reaction times and percentage errors over all subjects are presented in Table 2.

Looking at the nonwords first, a one-way analysis of variance with repeated measures on the one factor showed that there was an overall significant difference across the three conditions, *min* $F'(2, 33) = 4.99$, $p < .05$. Further analysis revealed that, as predicted, Condition 1 (PLAT) was associated with longer reaction times than both Condition 2 (BROT), *min* $F'(1, 33) = 4.28$, $p < .05$, and Condition 3 (PREN), *min* $F'(1, 33) = 9.02$, $p < .01$. In addition, Condition 2 did not differ from Condition 3, *min* $F'(1, 32) = 1.06$, $p > .05$, with neither $F_1(1, 14) = 3.14$ nor $F_2(1, 19) = 1.61$ being significant. An analysis of the errors revealed no difference across the three conditions, *min* $F'(2, 33) < 1$.

Analysis of the reaction-time data for the word conditions again revealed a significant difference across the three conditions, *min* $F'(2, 28) = 3.82$, $p < .05$. More detailed analysis showed that, as predicted, Condition 4 (NEIGH) was associated with longer reaction times than both Condition 5 (SHREW), *min* $F'(1, 25) = 4.70$, $p < .05$, and Condition 6 (SCOFF), *min* $F'(1, 28) = 7.39$, $p < .02$. In addition, Condition 5 did not differ from Condition 6, *min* $F'(1, 28) < 1$, with neither $F_1(1, 14) = 0.01$ nor $F_2(1, 14) = 0.01$ being significant. An analysis of the errors revealed no significant differences across the three conditions, *min* $F'(2, 23) = 1.12$, $p > .05$.

The results support the hypothesis that the first syllable of a polysyllabic monomorph has lexical status. Presumably, such a word would therefore be recognized by finding the lexical representation of its first syllable and then ascertaining from information stored in that entry whether or not the rest of its syllables can go together with the first syllable to form a word.

It appears, then, that polysyllabic single morphemes (e.g., PLATFORM, NEIGHBOR, ATHLETE) are recognized by the same

TABLE 2

MEAN CLASSIFICATION TIMES (MILLISECONDS), STANDARD ERRORS, AND PERCENTAGE ERROR RATES FOR NONWORD CONDITIONS 1, 2, AND 3 AND WORD CONDITIONS 4, 5, AND 6 (EXPERIMENT II)

Condition	Example	RT	*SE*	Percentage error
Nonwords				
(1) First syllable of word	PLAT	711	35	11
(2) Not first syllable of word	BROT	672	30	12
(3) Unrelated to words	PREN	654	30	8
Words				
(4) First syllable of another word	NEIGH	650	29	18
(5) Not part of another word	SHREW	602	24	16
(6) Unrelated to another word	SCOFF	603	26	10

procedure as are polysyllabic words containing two morphemes (e.g., DAYDREAM, TEXTBOOK). Thus, as far as lexical storage and retrieval are concerned, one may consider a nonmorphemic syllable (PLAT, ATH) and a morphemic syllable (DAY, TEXT) as being functionally equivalent.

Experiment III

The pattern of interference effects observed in Experiment I suggested that the last syllable of a polysyllabic word is not employed in the initial search process. If this interpretation is correct, then there would be no need to store the last syllable as a lexical entry. Therefore, the effects obtained in Experiment II should not hold if last syllables, rather than first syllables, are used as items. Thus, classification of CULE (from MOLECULE) as a nonword should show no interference effect, and, similarly, recognition of LEDGE as a word should not be affected by the existence of the word KNOWLEDGE.

Method

Materials. Condition 1 consisted of 15 nonwords which were derived by removing all but the last syllable of polysyllabic English words, that is, CULE (from MOLECULE). These were matched in length and in consonant–vowel arrangement with 15 nonwords which were not parts of any English words, that is, SUNE (Condition 2). Since Conditions 2 and 3 in Experiment II did not differ, it was felt that there was no need in this experiment to include a condition where the nonwords were last letters of words but not last syllables (like CALE from SCALE).

Condition 3 consisted of 15 words, each of which was the final syllable of a word of higher frequency, that is, LEDGE (where KNOWLEDGE has a higher frequency than LEDGE). Each Condition 3 word was matched in frequency with a word that was not part of any other more frequently occurring English word (e.g., PROBE). These items comprised Condition 4.

Results and Discussion

Table 3 presents mean reaction times and error rates across subjects.

As predicted, there were no differences between either the nonword conditions or the word conditions, *min* $F' < 1$ in both cases, with $F_1(1, 14) = 0.01$, $p > .05$ and $F_2(1, 14) = 0.02$, $p > .05$ for the nonwords and $F_1(1, 14) = 0.02$, $p > .05$ and $F_2(1, 14) = 0.003$, $p > .05$ for the words. There were no differences in error rates either, *min* $F' < 1$ in each case.

The results support the hypothesis that the last syllable of a word is not independently accessed for the recognition of that word, unlike the first syllable. This conclusion is consistent with the results obtained in studies in word restoration (Bruner & O'Dowd, 1958; Chambers, 1975) and redintegrative memory (Horowitz, White, & Atwood, 1968; Horowitz, Chilian, & Dunnigan, 1969;

TABLE 3

Mean Classification Times (Milliseconds), Standard Errors, and Percentage Error Rates for Nonword Conditions 1 and 2 and Word Conditions 3 and 4 (Experiment III)

Condition	Example	RT	*SE*	Percentage error
Nonwords				
(1) Last syllable of word	CULE	640	31	15
(2) Not last syllable of word	SUNE	639	31	10
Words				
(3) Last syllable of another word	LEDGE	553	20	8
(4) Not last syllable of another word	PROBE	552	20	7

Dolinsky, 1973). These studies have all suggested that the beginning fragment of a word, compared to a medial or a final fragment, contains the most information about what the whole word is.

Experiment IV

So far, we have dealt with cases where the syllable or constituent boundary is clearly marked by an extremely low probability letter combination or by a sequence that would, in fact, be illegal at any other position than at a syllable boundary. Would the same effects be expected if there were several possible syllabifications of the test items? For example, there are no orthographic considerations that force an analysis of TRUCERIN as TRUCE + RIN. The first syllable could be either TRU or TRUCE. In such cases, it might be expected that the effects of a word embedded in a nonword could be either nonexistent or considerably weakened.

The alternative is that the interference effects we have observed in previous experiments are in no way dependent on prior syllabification of the test item. If this were so, then WN nonwords with unclear syllable boundaries should be classified in the same way as WN nonwords with clear boundaries (like FOOTMILGE). So, both WN nonwords with clear syllable boundaries (e.g., LATCHMUN) and WN nonwords with unclear syllable boundaries (e.g., TRUCERIN) should take longer to classify than both NN nonwords which have unclear syllable boundaries (e.g., GLICERAX) and NN nonwords which have clear syllable boundaries (e.g., BONCHMIP).

Method

Materials. The WN nonwords with clear boundaries (e.g., LATCHMUN) were designed in the same way as the nonwords of the WN condition in Experiment I. Each of these was matched with a WN nonword with an unclear boundary (e.g., TRUCERIN) for both length and frequency of occurrence of the first constituent. Each of these WN nonword pairs was matched in length to a NN nonword with a clear boundary (e.g., BONCHMIP) and a NN nonword with an unclear boundary (e.g., GLICERAX). There were 16 such matching quadruplets and these are presented in the Appendix.

The distractor items were 48 polysyllabic words which were constructed in the same way as the nonword items; that is, words which consisted of a word followed by a nonword with a clear syllable boundary (e.g., SANDWICH), words consisting of a word followed by a nonword with an unclear syllable boundary (e.g., MINESTRONE), words consisting of two nonwords with a clear syllable boundary (e.g. TECHNIQUE), and words consisting of two nonwords with an unclear syllable boundary (e.g., PEDESTAL).

Results and Discussion

Reaction time and error rate means are presented in Table 4.

A 2×2 analysis of variance with repeated measures on each factor was carried out, the factors being clearness of boundary and lexical status of the first syllable. A significant main effect of the lexical status of the first syllable

TABLE 4

Mean Classification Times (Milliseconds), Standard Errors, and Percentage Error Rates for WN Nonwords with Clear and Unclear Boundaries and NN Nonwords with Clear and Unclear Boundaries (Experiment IV)

Condition	Example	RT	*SE*	Percentage error
Clear boundary				
WN	LATCHMUN	640	34	5
NN	BONCHMIP	594	26	4
Unclear boundary				
WN	TRUCERIN	643	38	5
NN	GLICERAX	603	28	2

was obtained, *min* $F'(1, 24) = 9.69$, $p < .01$, with WN nonwords taking longer than NN nonwords. However, there was no effect of clearness of boundary, *min* $F'(1, 29) < 1$, with $F_1(1, 14) = 0.34$ and $F_2(1, 14) = 0.26$, and there was no interaction between the two factors, *min* $F'(1, 25) < 1$, with $F_1(1, 14) = 0.50$ and $F_2(1, 14) = 0.20$. A similar 2×2 analysis of variance on the error data revealed no significant effects, *min* $F' < 1$ in each case.

It is apparent from the results that the clearness of the constituent boundary is irrelevant: WN nonwords take longer to classify than NN items regardless of how clearly the word constituent can be separated from the rest of the nonword. This implies that the access procedure responsible for the interference effects does not attempt to determine the syllable boundaries prior to access. But this conclusion creates problems. If the access system uses less than the whole word, then what is it that determines which subset of letters to use, if not the putative syllable boundary?

In attempting to solve this problem, it is necessary to postulate a segmentation procedure that always selects as an initial segment the sequence of letters that forms a word, if such a segment exists. Otherwise, the interference effects would not have been observed. The only solution we can find is to suggest that there is a procedure whereby a series of lexical searches is undertaken for successive letter combinations in the test item that begin with the first letter of that item. That is, for the item TRUCERIN, there is a search for T, TR, TRU, TRUC, TRUCE, and so on, until one of these letter combinations is found to correspond to a lexical entry (in this case, TRUCE). If no entry is found, then the item can be classified as a nonword at that point. But if an entry is found, then the contents of the entry would be examined to determine whether the remaining letters in the test item could be combined with the first syllable to form a valid English word. Such a strategy would not, of course, suffer any interference effects when the first syllable of a nonword item was not a word, even when the second syllable was a word.

In many cases, of course, a search from left to right will involve the accessing of *several* lexical entries, only one of which can be correct. For example, a search for the word HENCHMAN will encounter not only HENCH, but also HE and HEN. These latter two would be found to be inappropriate when it is ascertained that NCHMAN does not combine to form a word with a first *syllable* HE and CHMAN does not combine with a first syllable HEN. Of course, it is also possible that HE and HEN are rapidly discarded as potential first syllables when it is discovered that the remaining constituents would contain orthographically illegal sequences.

It is of some interest to note that the results of this experiment are very damaging to any theory that requires that access can only occur after the stimulus item has been recoded phonologically (e.g., Hansen & Rodgers 1968; Spoehr & Smith, 1973). For example, it seems most unlikely that TRUCERIN would be recoded with a phonological representation that preserves the pronunciation of TRUCE. In fact, according to the rules of Hansen and Rodgers, this item would be pronounced as TRU + CE + RIN. Thus, there would be no lexical entry for its first syllable, and, consequently, no interference effects would be observed.

So far, most of the evidence for the importance of the first syllable in lexical access has been derived from experiments using nonwords as test items. This is primarily due to the fact that the interference effect in the classification of nonwords, caused by the locating of a lexical entry, is such a powerful vehicle for word-recognition research. However, it is important to ensure that the first-syllable strategy is not somehow restricted to nonword items. Experiment V is addressed to this issue and examines whether the first syllable plays the same kind of role when polysyllabic words (in this case, polymorphemic words) are used as test stimuli.

Experiment V

If a compound word is recognized by accessing its first constituent, then the frequency of occurrence of the first constituent should influence reaction times. To illustrate: Although the words LOINCLOTH and HEADSTAND have the same frequency of occurrence according to the Kučera–Francis word count, the word LOIN is much less frequent than HEAD. Therefore, since compound words are recognized on the basis of their first constituents, and since high-frequency words are accessed before low-frequency words (Rubenstein, Garfield, & Millikan, 1970; Forster & Chambers, 1973; Taft & Forster, 1975), one would expect LOINCLOTH to take longer to classify as a word than HEADSTAND.

A similar frequency effect would be expected for WW and WN nonwords (e.g., DUSTWORTH, FOOTMILGE), if these items were classified as nonwords solely on the basis of information in the lexical entry that was found for their first syllable. However, it need not necessarily be true that the entry that is found for the first syllable is the *only* possible entry for that syllable. If the letters that form the first syllable can have several possible meanings, there may well be more than one lexical entry for that letter combination; for example, the entry SAND that is accessed for the recognition of SANDMAN, SANDBAG, and SANDPAPER would presumably be a different entry SAND to that accessed for the recognition of SANDWICH. Therefore, in the case of a WW or WN nonword, when it is found from information in the lexical entry for the first syllable that the second constituent does not combine with the first to form a word, a further lexical search for the first constituent would have to take place before classification as a nonword could be reliably made. This would be an exhaustive search. Since the search continues to the same point regardless of when the interruption to the search occurred, the frequency of the first constituent should *not* affect reaction times. This sort of argument was also used by Forster and Bednall (1976).

Thus, the predictions for this experiment are that for *words*, the frequency of occurrence of the first constituent will control reaction time, but that for nonwords, no such effect will be observed. More specifically, compound words that have low-frequency words as first constituents (LF word condition, e.g., LOINCLOTH) should take longer to classify than compound words that have high-frequency first constituents (HF word condition, e.g., HEADSTAND), and, second, compound nonwords that have low-frequency words as first constituents (LF nonword condition, e.g., STALEGRIP) should take no longer to classify than compound nonwords that have high-frequency first constituents (HF nonword condition, e.g., STONEFOIL).

Method

Materials. Twenty LF words (e.g., LOINCLOTH) were matched for length and overall frequency with 20 HF words (e.g., HEADSTAND). The items were divided into the two classes on the basis of the frequency of occurrence of their first constituent. The first constituent was considered as being of low frequency if it had a frequency value of 10 or below according to the Kučera–Francis word count.[1] The high-frequency constituents were of frequencies of 50 and above. Similarly, 20 LF nonwords (e.g., STALEGRIP) were matched for length with 20 HF nonwords (e.g., STONEFOIL).

All items are listed in the appendix.

[1] A few words, like HENCHMAN and LUKEWARM, which have a nonword first constituent, were considered as LF words, since a nonword is equivalent to an extremely rare word. In fact, Forster and Chambers (1973) found that very rare words were treated in the same way as nonwords in a naming task.

Results and Discussion

Mean reaction times and error rates over all subjects are presented in Table 5.

An analysis of the reaction times showed that, as predicted, LF words (LOINCLOTH) took significantly longer to recognize than HF words (HEADSTAND), *min* $F'(1, 25) = 5.82$, $p < .05$. The LF nonwords (STALEGRIP) did not differ from the HF nonwords (STONEFOIL) in their classification times, *min* $F'(1, 26) = 1.13$, $p > .05$, though the subject analysis did yield a significant F value, $F_1(1, 14) = 6.08$, $p < .05$. However, LF nonwords were more quickly recognized than HF nonwords and, hence, this is unlikely to be a normal frequency effect. The item analysis was not significant, $F_2(1, 19) = 1.35$, $p > .05$.

TABLE 5

MEAN CLASSIFICATION TIMES (MILLISECONDS), STANDARD ERRORS, AND PERCENTAGE ERROR RATES FOR HF AND LF WORDS AND HF AND LF NONWORDS (EXPERIMENT V)

Condition	Example	RT	*SE*	Percentage error
Words				
HF	HEADSTAND	598	27	5
LF	LOINCLOTH	629	28	9
Nonwords				
HF	STONEFOIL	827	60	7
LF	STALEGRIP	808	56	4

The analysis of errors produced no significant differences, either between the word conditions, *min* $F'(1, 30) = 1.04$, $p > .05$, or between the nonword conditions, *min* $F'(1, 30) = 0.59$, $p > .05$.

The results obtained again strongly support the notion that compound words are recognized on the basis of their first constituents; if the frequency of the first constituent is varied, then the recognition time for the word as a whole also varies, even though the frequency of the word as a whole is held constant.

This, however, does not preclude the possibility that the frequency of the word as a whole can also have an influence on the time taken to recognize the word. The decision that the second constituent can go together with the first constituent is likely to be influenced by the commonness of that constituent combination, that is, the frequency of the word as a whole. For example, the items HEADACHE and HEADSTAND were both used in this experiment, with the former taking 547 msec to recognize and the latter taking 640 msec. This would probably be because HEAD is more often followed by ACHE than by STAND, the frequency of HEADACHE being 5 and the frequency of HEADSTAND being 1.

The fact that the frequency of the first constituent does not affect classification times of compound nonwords adds support to the claim that the search must continue after it is discovered from the lexical entry for the first constituent that the second constituent is not a valid partner to the first. This result, along with those reported by Forster and Bednall (1976), make a strong case for the interpretation of frequency effects in terms of the order in which entries are searched.

GENERAL DISCUSSION

The five experiments discussed in this paper make the following points.

(1) The lexical entry for a polysyllabic word is accessed via a representation of its first syllable irrespective of whether or not this syllable is a word. Information in the lexical entry stipulates the possible combinations of letters that can follow the first syllable.

(2) Storage of polysyllabic words is the same regardless of how many morphemes the word possesses (however, see later for a discussion of prefixed words).

(3) To determine the first syllable of a word, a lexical search is undertaken for all of the letter combinations from left to right until an appropriate lexical entry is found.

An important question that should be raised is the general one of the definition of a syllable. The difficulties in defining a syllable are discussed by Hansen and Rodgers (1973) and, instead, they propose a Vocalic Center Group (VCG). A VCG is a syllable-like structure that is defined in phonological terms (as are most definitions of syllables, e.g., Bolinger, 1968; Mackay, 1974) as being the smallest pronunciational unit within which all rules of phonemic co-occurrence, that is, phonotactic rules, can be specified. Hansen and Rodgers (1968) and Spoehr and Smith (1973) present rules by which a word can be parsed into its VCGs. However, problems arise if we define the syllable or VCG in purely phonological terms. For instance, while the word SIGN would be considered phonologically as one syllable, in the related word SIGNIFY, the syllable break would occur between the G and the N. Thus, it would have to be that SIGN and SIGNIFY are accessed through different lexical entries, namely, SIGN and SIG, respectively. However, if one subscribes to a generative phonological theory (Chomsky & Halle, 1968), such a state of affairs is to be avoided, since the relationship between SIGN and SIGNIFY would be lost. Instead, one would have to postulate that the important unit of reading is some sort of *abstract* syllable that is not necessarily manifest in the pronunciation of the word. Thus, SIGN and SIGNIFY would both have the same first syllable, which might be either SIG or SIGN. The same problem arises with many other words, like THIRSTY (syllabified by Hansen and Rodgers' rules as being THIR + STY), FASTING (FAS + TING), and ACTOR (AC + TOR). If these words were stored in the lexicon on the basis of their phonologically defined first syllable, then the relationship between such pairs as THIRSTY and THIRST, FASTING and FAST, and ACTOR and ACT would be lost. Thus, it is likely that there is an abstract level of syllable representation which maintains the relationship between a suffixed word and its base form and that words are not stored on the basis of their pronunciation, as Hansen and Rodgers, and Spoehr and Smith, would hold.

It should be noted that, even if a reader is not consciously aware of what is stored in his lexicon, which would be the case if abstract representations are stored, he should nevertheless have no difficulty in accessing appropriate lexical entries according to the model of word recognition proposed in this paper. Since a search is conducted on letter combinations from left to right, the reader will eventually use the correct letter combination that encounters the appropriate lexical entry.

The notion that only the first syllable of a polysyllabic word is used in the accessing of lexical information, however, is seemingly in conflict with the proposal put forward by Taft and Forster (1975) that a prefixed word (e.g., REJUVENATE) is recognized on the basis of its stem (JUVENATE). By definition, it is the prefix, not the stem, that is the first syllable of a prefixed word. However, the conflict is easy to resolve. Obviously, prefixes must be listed in the lexicon or else they could not be recognized as prefixes. Hence, we can assume that the left-to-right search technique will first isolate the prefix as the initial syllable, but when it is discovered that the first syllable is a prefix, the search begins again from the first letter after the prefix. That is, the prefix is "stripped off." Thus, the only modification to the theory required to accommodate the findings for prefixed words with those for polysyllabic words is that the term "first syllable" should be taken to mean "first syllable after the prefix (if any)." This would permit items such as MISHAP and HAPPEN, INSPECT and SPECTATOR to be stored together, namely, in the lexical entries HAP and SPECT, though there has been no evidence produced to say that this is actually the case.

Throughout this report, we have avoided extensive discussion of alternative explanations of the data. This has been mainly in the interests of clarity and should not be taken to imply that there are no viable alternatives or that we have not considered them. Most of the theoretical claims made would, however, be unchanged if we were to switch to a totally different model of word recognition, that is, a direct-access content-addressable memory. The three major claims made at the beginning of this discussion section would still stand, although the wording of the third claim would have to be altered to eliminate any reference to "search." In our view, the only result that might commit one to a search model is the finding in Experiment IV that frequency of the first syllable is relevant only when the item is a word.

It is possible that, in constructing items for each of the experiments, we have unintentionally confounded some totally extraneous variable with the treatment variable. In the case of nonwords, for example, we may have accidentally selected items that varied systematically in their "wordness" properties. The nonwords of one condition may have been more pronounceable than the nonwords of another condition. It is, of course, extremely difficult to show that the variable selected by the experimenters is the only relevant variable. One can only subject the hypothesis to as many different tests as possible, in each case relying on the *min F′* test to demonstrate generality across items, thereby making it improbable that the effects are due to extraneous variables. However, this procedure will not eliminate the effects of any systematically confounded variable. Until we have a reliable method for evaluating the properties of nonwords, the possibility of there being systematically confounding variables will remain.

The same difficulties are not nearly as problematical when the test items are words, since there is much less freedom in selecting words than is the case for nonwords. In this respect, it should be noted that several of the experiments also used words as stimuli and it would have to be argued that the systematically confounded variable present in the sample of nonwords was also present in the sample of words. Given the very stringent criteria for selecting words in these experiments (e.g., being the first syllable of a more frequent word), this seems most unlikely.

APPENDIX

Below are listed the items used in each experiment, together with the mean lexical decision time for the item.

Experiment I

The items are arranged in quadruplets, with a WW nonword followed by a matching WN, NW, and NN item:

brieftax 755, cleanmip 824, thernlow 632, spilkwut 693; topdrug 738, redblin 751, homrank 670, radmosh 681; hearfew 718, hallwub 722, gurmday 767, vashpon 682; flowgun 745, flatbew 725, belfhit 689, haldneg 674; lotcool 671, asktarp 734, nasfund 627, erkfand 679; oddhard 682, sumwoll 720, orktype 624, bixmook 678; toastpull 805, spellcung 706, flurbpair 642, thrimnade 697; formmind 805, bestpilt 800, toopcase 792, gindtrem 673; dustworth 782, footmilge 888, trowbreak 667, mowdflisk 661; gasbay 770, oilrad 756, lisfat 683, rogchy 660.

Experiment II

Nonword items. The items are arranged in triplets, with a Condition 1 nonword followed by its matched Condition 2 and Condition 3 control item, the letters in parentheses being the letters that have been removed:

hench 883 (MAN), splot 710 (CHED), shult 702; tad 712 (POLE), faw 701 (N), ged 642; trom 649 (BONE), traw 647 (LER), trup 593; cran 693 (BERRY), scam 711 (PERING), blet 587; chim 639 (NEY), plig 612 (HT), chon 596; scound 728 (REL), draugh 642 (TS), spoard 700; plat 699 (FORM), brot 686 (HER), pren 565; shuff 756 (LE), twing 774 (E), shink 841; yester 740 (DAY), patien 590 (T), yetian 617; bund 714 (LE) nint 673 (H), murt 691; strug 785 (LE), maint 707 (AIN), slift 837; voy 679 (AGE), rop 709 (E), lom 651; fash 688 (ION), libe 705 (RAL), fave 694; cust 794 (OMERS), mank 662 (IND), denk 688; samp 730 (LE), welf 652 (ARE), selp 634; ambass 727 (ADOR), archit 669 (ECT), almith 630; pract 663 (ICE), healt 762 (H), thart

610; chall 677 (ENGE), worsh 659 (IP), crish 643; ath 669 (LETE), awf 645 (UL), arn 673; caval 797 (RY), dilem 667 (MA), covim 604.

Word items. The items are arranged in triplets, with a Condition 4 word followed by its Condition 5 and Condition 6 control words, the letters in parentheses being the letters that have been removed:

neigh 754 (BOUR), shrew 627 (D), scoff 734; sham 733 (ROCK), bran 741 (CH), fern 597; moth 615 (ER), boar 556 (D), frog 517; stab 628 (LE), toot 603 (H), loot 571; thresh 812 (OLD), supple 612 (MENT), maggot 650; tick 593 (ET), pier 617 (CE), turf 622; colon 775 (EL), locus 577 (T), venom 640; tack 602 (LE), mole 587 (CULE), loaf 555; candid 607 (ATE), patter 633 (N), morsel 621; garb 770 (AGE), clot 577 (H), thud 644; bib 675 (LE), fir 627 (ST), nun 626; mast 613 (ER), brow 577 (N), loom 622; cult 576 (URE), sigh 646 (T), calf 542; log 543 (IC), beg 544 (AN), egg 541; muff 709 (LE), dial 560 (OGUE), romp 624.

Experiment III

Nonword items. The items are arranged in pairs, with a Condition 1 nonword followed by its Condition 2 control, the letters in parentheses being the letters that have been removed:

cule 630 (MOLE), sune 633; lete 574 (ATH), tepe 590; strone 706 (MINE), splike 775; flage 717 (CAMOU), chipe 710; toise 702 (TOR), fouse 639; pult 677 (CATA), bift 686; wark 663 (BUL), tork 639; marm 718 (SCHOOL), durd 620; drome 627 (SYN), brone 681; ine 665 (MACH), ake. 630; lum 646 (HOOD), rom 626; ner 543 (PART), lir 578; thon 568 (MARA), chom 605; surp 628 (U), solf 621; nique 654 (TECH), bogue 661.

Word items. The items are arranged in pairs, with a Condition 3 word followed by its Condition 4 control, the letters in parentheses being the letters that have been removed:

cape 550 (ES), crop 526; fare 589 (WAR), lure 602; ledge 499 (KNOW), probe 578; reign 530 (SOVE), plank 524; graph 563 (PHOTO), grasp 521; band 514 (HUS), seat 512; sand 492 (THOU), dawn 497; mite 680 (DYNA), moot 675; sphere 586 (ATMO), thrust 559; ice 482 (SERV), odd 565; kin 605 (NAP), fry 525; pet 498 (CAR), pad 512; lain 575 (CHAP), pail 605; hood 562 (LIKELI), soak 562; chant 612 (MER), prowl 565.

Experiment IV

The items are arranged in quadruplets, with a WNC nonword followed by a matching NNC nonword, WNU nonword, and WNC nonword:

joinlird 654, doinrint 613, pagelont 620, tagerald 613; warmvoost 662, woamfeard 627, flataunch 649, flodainst 637; thawherk 560, trawyunt 563, sofanulk 565, tafomunt 568; latchmun 635, bonchmip 593, trucerin 588, glicerax 594; chefpite 606, thifbure 586, trionade 723, driotane 627; slowhent 672, spowhink 616, treepold 679, sneepisk 622; quietpeld 747, quindbilt 639, framelume 694, frinetoke 593; howlboop 655, morlboin 596, hikelork 693, nipelond 652; hotelrin 577, satelrop 593, radiocag 572, lodionug 549; tartconce 626, mormsarse 641, stiroarse 661, clurierce 609; rockfeft 709, leckpept 599, votemimp 607, wikenink 646; sendbosh 622, fardbith 617, richoast 661, nishount 562; limbgand 659, fambtald 567, lushorld 644, fothanch 610; bustfoar 619, duntvair 569, dametimp 693, ronetunk 564; dognala 650, jegmara 570, barotta 684, horissa 596; padlato 663, tidnilo 541, rotaspo 583, dopilto 619.

Experiment V

Word items. The items are arranged in pairs, with an LF word followed by its matching HF word:

warehouse 587, milestone 576; loincloth 646, headstand 640; ribcage 724, eyelash 552; grapevine 629, classmate 532; henchman 623, shortcut 589; skullcap 643, deathbed 633; poppyseed 620, riverboat 558; treadmill 660, bloodshot 590; soothsayer 669, housepaint 619; frostbite 625, checklist 610; teenage 543, wildcat 541; dockside 663, handbook 546; junkyard 593, timebomb 648; lukewarm 602, headache 547; thumbnail 690, spacesuit 623; soybean 647, seaweed 599; tugboat 597, warlord 666; swineherd 646, stockpile 603; yesterday 537, everyone 599; pawnshop 650, woodwind 641.

Nonword items. The items are arranged in pairs, with an LF nonword followed by its matching HF word:

grindpath 764, grasscast 969; pigbulk 807, farsoup 807; cavetap 814, caselip 906; swapnerve 767, stopspark 750; stalegrip 862, stonefoil 891; cloakbud 787, sweetrag 868; heaverace 828, judgerise 773; hikedrug 819, finerank 864; crisplobe 775, monthgasp 907; hugcalf 808, askdash

812; hedgedate 915, watchrole 922; dumptail 894, carejump 806; clownhip 837, cleandig 750; smashboss 794, smilecrop, 831; cheerturf 798 piecetick 884; hogtide 840, hotsigh 792; slopharsh 776, testshelf 818; cagefan 788, needrod 724; glintmeat 725, provecoat 810; petdamp 777, putflag 727.

References

Bolinger, D. *Aspects of language.* New York: Harcourt, Brace and World, 1968.

Bruner, J. S., & O'Dowd, D. A note on the informativeness of parts of words. *Language and Speech*, 1958, **1**, 98–101.

Chambers, S. M. *Orthographic analysis during word recognition.* Paper presented at the Experimental Psychology Society Conference, University of Sydney, May 1975.

Chomsky, N., & Halle, M. *The sound pattern of English.* New York: Harper and Row, 1968.

Dolinsky, R. Word fragments as recall cues: Role of syllables. *Journal of Experimental Psychology*, 1973, **97**, 272–274.

Forster, K. I., & Bednall, E. S. Terminating and exhaustive search in lexical access. *Memory and Cognition*, 1976, **4**, 53–61.

Forster, K. I., & Chambers, S. M. Lexical access and naming time. *Journal of Verbal Learning and Verbal Behavior*, 1973, **12**, 627–635.

Gibson, E. J., & Guinet, L. Perception of inflections in brief visual presentations of words. *Journal of Verbal Learning and Verbal Behavior*, 1971, **10**, 182–189.

Hansen, D., & Rodgers, T. S. An exploration of psycholinguistic units in initial reading. In K. S. Goodman (Ed.), *The psycholinguistic nature of the reading process.* Detroit: Wayne State University Press, 1968.

Horowitz, L. M., Chilian, P. C., & Dunnigan, K. P. Word fragments and their redintegrative powers. *Journal of Experimental Psychology*, 1969, **80**, 392–394.

Horowitz, L. M., White, M. A., & Atwood, D. W. Word fragments as aids to recall: The organization of a word. *Journal of Experimental Psychology*, 1968, **76**, 219–226.

Jarvella, R. J., & Snodgrass, J. G. Seeing ring in rang and retain in retention: On recognizing stem morphemes in printed words. *Journal of Verbal Learning and Verbal Behavior*, 1974, **13**, 590–598.

Kintsch, W. Abstract nouns: Imagery versus lexical complexity. *Journal of Verbal Learning and Verbal Behavior*, 1972, **11**, 59–65.

Kučera, H., & Francis, W. N. *Computational analysis of present-day American English.* Providence, R. I.: Brown University Press, 1967.

MacKay, D. G. Aspects of the syntax of behavior: Syllable structure and speech rate. *Quarterly Journal of Experimental Psychology*, 1974, **26**, 642–657.

Murrell, G. A., & Morton, J. Word recognition and morphemic structure. *Journal of Experimental Psychology*, 1974, **102**, 963–968.

Norman, D. A. (Ed.). *Models of human memory.* New York: Academic Press, 1970.

Rubenstein, H., Garfield, L., & Millikan, J. A. Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, 1970, **9**, 487–494.

Snodgrass, J. G., & Jarvella, R. J. Some linguistic determinants of word classification times. *Psychonomic Science*, 1972, **27**, 220–222.

Spoehr, K. T., & Smith, E. E. The role of syllables in perceptual processing. *Cognitive Psychology*, 1973, **5**, 71–89.

Taft, M., & Forster, K. I. Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, 1975, **14**, 638–647.

(Received December 1, 1975)