Memory & Cognition
1992, 20 (3), 219-230

The role of syllabic and orthographic properties of letter cues in solving word fragments

KAVITHA SRINIVAS
Boston College, Chestnut Hill, Massachusetts

HENRY L. ROEDIGER III
Rice University, Houston, Texas

and

SUPARNA RAJARAM
Temple University School of Medicine, Philadelphia, Pennsylvania

The present research examined the role of phonological and orthographic properties of cues in mediating the retrieval of words from the mental lexicon. The task required subjects to resolve fragmented words when provided with semantically related cues (e.g., spiteful: _ _ _DIC_ _ _ _). Phonological properties of the letter cues were manipulated such that the letters either corresponded to the syllables (e.g., DIC in *vindictive*) or nonsyllables (NDI) in the word. Orthographic properties of the letter cues were manipulated by selecting letter groups that either co-occurred frequently in the language or did not. In two experiments, results revealed little or no effect of the phonological variable (syllables) but a reliable effect of the orthographic variable (letter-cue frequency). Letter cues with a low frequency of co-occurrence in the language led to better completion of the fragmented words. We interpret these findings as support for models of lexical representation that are based on orthographic properties (e.g., Seidenberg & McClelland, 1989) rather than those based on phonological constraints.

The research reported in this paper is directed at the issue of how our mental lexicon is organized. To explore the issue, we used a task, the crossword-puzzle-solving paradigm, that Goldblum and Frost (1988) developed for this purpose. In this task, subjects are required to solve fragmented words given semantic cues (e.g., spiteful: _ _ _DIC_ _ _ _). By manipulating the properties of the letter cues provided, it is possible to determine whether a particular property is represented in the mental lexicon. Using this procedure, Goldblum and Frost concluded that syllables play an important role in mediating word retrieval in this task and that syllables form an important part of lexical representation. However, before describing our own research using their paradigm, we review related research in the area of word recognition that also addresses the issue of lexical representation.

A common assumption of many theories of word recognition is that complex words are represented in the mental lexicon in sublexical units that mediate access to the words. The nature of these sublexical units varies with the theory in question. For example, in Spoehr and Smith's (1973) model of visual word recognition, the sublexical units are assumed to be syllable-like units called vocalic center groups (VCGs). Orthographic VCGs are assumed to be spellings of phonologically defined VCGs, which are the minimal pronunciation units of the language for which articulatory constraints are fully specified (Hansen & Rodgers, 1968). In Spoehr and Smith's (1973) model, these VCG units are identified by iteratively applying a set of syllabification rules proposed by Hansen and Rodgers (1968).

Spoehr and Smith (1973) reported empirical support for this model by showing that subjects were more likely to report target letters in briefly presented one-syllable words (e.g., PAINT) than in two-syllable words (e.g., PAPER) when the words were of the same length and had the same initial consonant. They also reported that subjects were more likely to correctly identify target letters in briefly presented nonword strings if the strings contained syllables (e.g., BLOST) than if they did not (e.g., LSTB), which suggests that syllabic clusters are processed faster than nonsyllabic clusters (Spoehr & Smith, 1975).

However, recent evidence for the idea that syllables are represented as sublexical units in the mental lexicon has been mixed. On the one hand, many studies have found evidence for syllabic units in several different paradigms (e.g., Mewhort & Beal, 1977; Neely, Crawley, & Vellutino, 1990; Prinzmetal, Treiman, & Rho, 1986). For instance, Prinzmetal et al. used the "illusory conjunction" paradigm to explore the issue. Illusory conjunctions (Treisman & Schmidt, 1982) refer to the finding that when subjects are briefly presented with a string of colored letters,

The experiments reported in this paper were presented at the 1990 meeting of the American Psychological Society, Dallas. We wish to thank R. Frost, D. L. Nelson, and D. L. Schacter for their insightful reviews. Correspondence should be addressed to K. Srinivas, Department of Psychology, Boston College, Chestnut Hill, MA 02167-3807.

they often report the colors and letters in incorrect combinations (more often than expected by chance). Furthermore, these illusory-conjunction errors are influenced by the structural properties of the letter strings (Prinzmetal & Millis-Wright, 1984) such that they are more likely to occur in letter strings that form a perceptual unit (e.g., words such as *age*) than in letter strings that do not (e.g., pseudowords such as *vgh*). Prinzmetal et al. therefore argued that if syllables are the sublexical units that mediate access to words, illusory conjunctions should be more likely to occur between colors and letters within a syllable than colors and letters between syllables. They used two-syllable, five-letter words (e.g., *anvil*) and found that subjects were more likely to incorrectly combine target letters (such as the *v* in *anvil*) with the color of other letters within the syllable (such as the color of *i* or *l*) than the color of other letters that belonged to a different syllable (such as *a* or *n*), which suggests indirectly that syllables are the sublexical units that mediate word recognition.

On the other hand, several studies that have explored the role of syllables in mediating access to visually presented words have yielded inconsistent results. For instance, on tasks requiring a *same–different* judgment for two simultaneously presented words, the effect of increasing the number of syllables in the pair of words that had to be compared had no consistent effect on response time (Klapp, 1971; Taylor, Miller, & Juola, 1977). Similar inconsistencies have been reported with word-naming and lexical decision tasks. Klapp, Anderson, and Berrian (1973) reported that the time to start vocalization on a word-naming task was longer for two-syllable words than for one-syllable words. However, other studies have reported no effect of number of syllables on initiation of word naming (e.g., Forster & Chambers, 1973; Frederiksen & Kroll, 1976; Richardson, 1976) or on making lexical decisions (e.g., Forster & Chambers, 1973; Frederiksen & Kroll, 1976). Lima and Pollatsek (1983) did find an effect of number of syllables on lexical decision, but the effect was not consistently obtained in their experiments. For instance, when words were segmented spatially in a lexical decision task, a syllabic division (e.g., BUR DEN) resulted in faster response times than did a nonsyllabic division (e.g., BURDE N). However, when the beginning syllables of words (e.g., BUR) were used to prime the target (BURDEN), facilitating effects of priming over a no-prime control occurred in one experiment (Experiment 2) but not in another (Experiment 3).

What could be the basis of these inconsistent results? It could be argued that there is no theoretical consensus on what constitutes a syllabic unit in English (see Seidenberg, 1989, for this argument). Different linguistic theories seem to apply different rules for syllabification. For instance, a bisyllabic word such as CAMEL would be syllabified as CAM/EL by Hoard's (1971) syllabification rules, as CA/MEL by Hansen and Rodgers's (1968) rules, and as CAM/MEL by Kahn's (1976) rules. Perhaps the inconsistent results observed in the literature are a result of linguistically naive definitions of syllables.

A second line of argument refers to the nature of the tasks used to explore this issue in the literature (Goldblum & Frost, 1988; Seidenberg, 1987). It has been argued that most of the methods used to explore the issue of how the mental lexicon is organized have serious limitations. For instance, the lexical decision task is greatly affected by the particular strategies that a subject adopts in the experiment (e.g., Neely, 1991; Shulman, Hornak, & Sanders, 1978). Similarly, it has been argued that naming latencies will not be sensitive to sublexical units if subjects initiate their responses before they have completed processing of the word (e.g., Frederiksen & Kroll, 1976; Henderson, 1985). In addition, naming latencies may be reflecting processes related to articulation rather than processes related to recognition and retrieval of words (Balota & Chumbley, 1985; Klapp et al., 1973). It has also been suggested that segmenting or marking syllables in a word may induce a strategy in subjects to use these units when the units might have been ignored otherwise (Seidenberg, 1987).

A third alternative is that syllables are not represented in the mental lexicon; they are merely correlated with some other property of words that is crucial for the recognition and retrieval of words. One property that is correlated with syllabicity is the orthographic redundancy in written words. Orthographic redundancy refers to the fact that there are sequential dependencies between letters in written words. For instance, if a word begins with *t*, its second letter will probably be an *h*, an *r*, a *w*, or a vowel, and there are substantial differences in the probabilities with which each of these letters will occur. Adams (1981) observed that letters within the syllables (e.g., *an.vil*) are often marked by the co-occurrence of letters that occur frequently in the language relative to letters that straddle the syllable boundary (e.g., NV in *anvil*). In fact, she suggested that this correlation between orthographic redundancy and syllabicity may be used as a heuristic in parsing complex words into syllables: a syllable boundary typically bisects the two letters that have the lowest frequency of co-occurrence in a word. Given that there is inconsistent evidence for the role of syllables in the representation of words in the lexicon, it is possible that this correlated property of orthographic redundancy in letter units is more critical in mediating access to words than is the syllabic nature of the letter cues.

Seidenberg (1987) presented evidence that bears on this issue using the paradigm of illusory conjunctions earlier employed by Prinzmetal et al. (1986). He compared illusory conjunctions for words that were orthographically similar but differed in the number of syllables they contained, such as *naive* and *waive* (where *naive* has two syllables and *waive* has only one). Seidenberg reasoned that if syllables are the sublexical units involved in word recognition, subjects should incorrectly combine the target letter (e.g., *i* in *naive*) with the color of the letters within the syllable (*v* and *e*) rather than with letters from another syllable (*n* and *a*). This tendency should not occur in single-syllable words (*waive*). However, Seidenberg found the same pattern of results in both types of words, so that the letter cluster IVE functioned as a unit regardless of whether the letters constituted a syllable in a word (as in *naive*) or whether they did not (as in *waive*). These results suggest that it is unlikely that syllables are represented in the mental lexicon; rather, orthographic properties that are sometimes correlated with syllabicity form an important part of lexical representation.

More recently, though, Goldblum and Frost (1988) reported additional evidence suggesting that syllables are the sublexical units of words even when the effects of orthographic redundancy are controlled. They used the word-retrieval paradigm described earlier to examine whether syllabic clusters mediate access to words. To reiterate, in their task, subjects solved items like those in crossword puzzles (e.g., spiteful: _ _ _DIC_ _ _ _) when given a semantic clue and a fragmented word. Letter cues given during testing were either syllables in the word (e.g., _ _ _DIC_ _ _ _ in the word *vindictive*), pronounceable nonsyllables (e.g., _ _ _ _ICT_ _ _), unpronounceable nonsyllables (e.g., _ _NDI_ _ _ _ _), or nonadjacent letters (e.g., _ _N_I_T_ _ _). Orthographic redundancy was controlled by equating the four cuing conditions on mean trigram frequency. Trigram frequency refers to a measure of the frequency with which three letters co-occur in the English language as represented in the norms of Underwood and Schulz (1960).

The results indicated that any cluster of adjacent letter cues facilitated retrieval of the word relative to the case where the letters were dispersed. The interesting result was that syllabic letter cues yielded a reliable advantage over the nonsyllabic cues even though the average trigram frequency of the letter units in the two types of cues was equated. This syllabic advantage did not appear to be a function of pronounceability because pronounceable nonsyllabic cues did not differ from the unpronounceable nonsyllabic cues in their effectiveness in producing the target word. Goldblum and Frost (1988) interpreted these results as support for the notion that syllabic sublexical units mediate access to words in the lexicon.

We were intrigued by these results because, contrary to Seidenberg's (1987) findings, they suggested that even when orthographic properties of words are controlled, syllables act as the sublexical units that mediate access to complex words. How could these discrepant findings be reconciled? One possibility was that Seidenberg (1987) controlled orthographic redundancy between words in the "syllable" and "nonsyllable" conditions by matching pairs of words in these conditions that were orthographically similar (e.g., *naive* or *waive*, respectively), whereas Goldblum and Frost (1988) controlled for orthographic redundancy between the "syllable" and "nonsyllable" conditions by equating these cuing conditions on mean trigram frequency. Given the design of the Goldblum and Frost (1988) study, it was impractical for them to control orthographic redundancy by matching the four types of cues for each word on trigram frequency. However, it is possible that this difference in control for the orthographic variable accounted for the discrepancy in the results. The present experiments were an attempt to explore this hypothesis.

In addition, we wanted to investigate the relative role of orthographic properties (such as trigram frequency) and linguistic properties (such as syllabicity) on the completion of fragmented words. The role of trigram frequency of the letter cues in solving fragmented words was not clear from the Goldblum and Frost (1988) study because they did not manipulate trigram frequency. We reasoned that trigram frequency was likely to affect the completion of fragmented words because letter cues with low trigram frequency specify the correct solution more than do words with high trigram frequency. For instance, NOL in *technology* has a lower trigram frequency than does POS in *imposter* because it is contained in fewer other words. Thus, the aim of these experiments was twofold: first, to determine whether an advantage in word-fragment completion would be observed for syllabic cues when syllabic and nonsyllabic cues for each word were matched for trigram frequency on an item-by-item basis, and second, to determine whether manipulating trigram frequency of the letter cues would influence the completion of fragmented words, regardless of whether the letter cues formed syllables.

To achieve our design, we selected four sets of words such that the letter cues in each word conformed to specific combinations of syllabic/nonsyllabic and low/high trigram frequencies. The first two groups consisted of words where the syllabic and nonsyllabic cues for each word had approximately the same trigram frequency. In one group, both syllabic and nonsyllabic cues of the word were low-frequency trigrams in the English language such as technology/_ _ _ _nol_ _ _/_ _ _hno_ _ _ _ (*nol* has a trigram frequency of 6 in a sample of 37,000 words; *hno* has a trigram frequency of 2). In the other group, both syllabic and nonsyllabic cues were high-frequency trigrams such as vindictive/_ _ _dic_ _ _ _/_ _ndi_ _ _ _ _ (*dic* has a trigram frequency of 117, *ndi* a frequency of 183). These conditions were selected to replicate Goldblum and Frost's (1988) findings, with a different type of control for the orthographic properties of letter cues. To reiterate, Goldblum and Frost (1988) equated the mean trigram frequency of the cues in the syllabic and nonsyllabic conditions. In our experiments, the syllabic and nonsyllabic letter cues were matched for their trigram frequency on an item-by-item basis and for the overall trigram frequency. On the basis of their findings, we expected to find an advantage for syllabic cues even when syllabic and nonsyllabic cues for each word were equated for trigram frequency on an item-by-item basis.

The other two item groups consisted of words where the syllabic and nonsyllabic cues for each word had reliably different trigram frequencies. In one group, the syllabic cues were low-frequency trigrams and the nonsyllabic cues were high-frequency trigrams, such as conveyor/_ _ _vey_ _/_ _nve_ _ _ (*vey* has a trigram frequency of 2; *nve* has a frequency of 150). In the other group, syllabic cues were high-frequency trigrams and nonsyllabic cues were low-frequency trigrams, such as microscope/ _ _cro_ _ _ _ _/_icr_ _ _ _ _ _ (*cro* has a trigram frequency of 185; *icr* has a trigram frequency of 2). These groups were designed to explore the relative importance of syllables and trigram frequency on the completion of fragmented words. If syllabicity of letter cues is the only important variable for the completion of fragmented words, a syllabic advantage should be obtained for both groups of words. However, if trigram frequency is also important for the completion of fragmented words such that low-frequency trigrams facilitate performance relative to high-frequency trigrams, a different pattern of results should be observed for the two groups. The advantage for syllabic cues should be enhanced when the syllabic cues are low in trigram frequency and nonsyllabic cues are high in trigram frequency because both syllabicity and low trigram frequency should result in an advantage for the syllabic cues. However, this advantage should be attenuated (or even reversed) when syllabic cues are high in trigram frequency and nonsyllabic cues are low in trigram frequency because the advantage of letter cues being syllables should presumably be offset by the disadvantage of their high trigram frequency. Experiment 1 tested these predictions.

EXPERIMENT 1

Method

Subjects. Thirty-two Rice University undergraduates participated in this experiment in partial fulfillment of a course requirement.

Design and Materials. Trigram frequency of syllabic cues (low or high) was crossed with trigram frequency of nonsyllabic cues (low or high) to create four sets of materials. Trigram frequencies for each letter cue were taken from the Underwood and Schulz norms (1960), and they reflected the frequency with which the three-letter cues co-occurred in a sample of about 37,000 words (2,080 words sampled from the Thorndike–Lorge lists, 15,000 words from written passages, and 20,000 words from Pratt's, 1939, norms with text material).

In two sets, syllabic and nonsyllabic cues were equated for trigram frequency (see Table 1 for mean trigram frequency and standard deviations in each condition). Set 1 consisted of words where both syllabic and nonsyllabic cues for each word had low trigram frequencies (mean: 5.1 for syllables, 4.1 for nonsyllables). Set 2 consisted of words where both syllabic and nonsyllabic letter cues for each word had high trigram frequencies (230.2 for syllables, 211.9 for nonsyllables). In the other two sets, high or low trigram frequency was crossed with syllabicity. Set 3 consisted of words with low-frequency syllabic cues (4.9) but high-frequency nonsyllabic cues (207.7) for each word. Set 4 consisted of words with high-frequency syllabic cues (216.2) but low-frequency nonsyllabic cues (4.7).

The trigram frequencies for all low-frequency cues were statistically equivalent across the four sets regardless of whether they were syllabic or nonsyllabic cues [$F(3,76) < 1$]. Similarly, the differences in trigram frequencies for all high-frequency cues were statistically equivalent across the four sets [$F(3,76) < 1$]. In addition, the 80 words used in the sets were selected so that they were 7 to 12 letters long and had at least three syllables. The four sets of items were matched for overall word frequency (Kučera & Francis, 1967) and for word length (see the means and standard deviations in Table 1). Statistical analysis showed no differences between the four sets of words on overall word frequency [$F(3,76) < 1$] or on word length [$F(3,76) = 1.19, p > .20$]. The full set of materials appears in the Appendix.

For each of the 80 words, two trigrams were selected such that one could serve as a syllabic cue for the word and the other could serve as a nonsyllabic cue for the word. Thus, each word served as its own control. Syllabic cues were defined for each word according to the *Oxford American Dictionary* (1980). Both syllabic and nonsyllabic cues were always composed of two consonants and a vowel. The cues were also chosen so that they never occurred at the beginning or end of the word. Previous research has shown that beginning and end cues are easier to solve than middle fragments (Dolinsky, 1973; Horowitz, Chilian, & Dunnigan, 1969; Horowitz, White, & Atwood, 1968). Both syllabic and nonsyllabic cues were drawn from middle positions in the word to control for position effects. Most nonsyllabic cues were composed of one or two letters of the syllabic cues along with a letter from an adjacent syllable. This ensured that syllabic and nonsyllabic cues were drawn from roughly the same positions in the word. No syllabic or nonsyllabic cues served as a cue for more than one word in the study. Thus, if the trigram DIC had been used as a syllabic cue for a word (e.g., *vindictive*), it was not used again as a cue for another word (e.g., *prediction*).

Semantic cues were constructed for each word so that each cue was either an associate or a rough synonym of that word. The semantic cues were chosen to be weak associates of the target word so that subjects would be forced to pay attention to the letter cues in order to solve the fragments instead of relying on the semantic cues alone.

Each subject was presented with semantic cues and letter cues from all four sets. Within each set, half of the letter cues presented to the subject were syllabic and the other half were nonsyllabic. Items were counterbalanced so that no subject saw the same word

Table 1
Means and Standard Deviations for Overall Word Frequencies, Word Length, and Trigram Frequencies for the Four Sets of Items

	Set 1 LF Syllabic LF Nonsyllabic		Set 2 HF Syllabic HF Nonsyllabic		Set 3 LF Syllabic HF Nonsyllabic		Set 4 HF Syllabic LF Nonsyllabic	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Overall word frequency	6.8	10.5	7.2	11.6	5.8	9.2	6.8	8.6
Word length	9.1	0.9	9.9	1.4	9.5	1.3	9.5	1.5
Syllabic trigram frequency	5.1	3.3	230.2	130.3	4.9	4.2	216.2	119.9
Nonsyllabic trigram frequency	4.1	3.4	211.9	133.9	207.6	139.4	4.7	3.6

Note—LF = low frequency; HF = high frequency.

in both the syllabic and the nonsyllabic conditions and each word was used equally often in the two conditions across subjects. This resulted in two test lists, each of which was presented in two different orders. Half of the subjects were tested on one order for a given list, and half were tested on the other.

Procedure. The subjects were tested in groups (of up to 3) on IBM-compatible computers. The subjects were instructed that they would perform a crossword-puzzle-solving task and were given examples of the task. Each trial was preceded by a warning signal ("Get ready") for 2 sec, followed immediately by a semantic cue and the fragment. The subjects were instructed to use the semantically related word and the letter cues from the word to solve the fragment. The subjects were also informed that in cases where the fragmented word was a category name for the semantic cue, the semantic cue would be preceded by the term "e.g." (for *nutrient*, the semantic cue was "e.g., vitamin"). As soon as they could think of a solution for the fragment, the subjects were instructed to press a key labeled "Y." Once they pressed the key, they were prompted to type in the solution. Thus, latencies and responses were recorded on the computer. A maximum of 15 sec was given for each fragment for the keypress. Once the subjects pressed the key, they were asked to type in the solution immediately. If the subjects were unable to find a solution for the fragment within 15 sec, the computer screen was cleared and the subjects pressed the "Enter" key to start the next trial. No feedback was given. The entire session lasted approximately 45 min.

Results and Discussion

Table 2 shows the mean proportion of fragmented words correctly completed as a function of different trigram frequencies of syllabic and nonsyllabic cues. The data indicated no advantage for syllabic cues over nonsyllabic cues when the cues were matched for trigram frequency (Sets 1 and 2). Thus, when both syllabic and nonsyllabic cues were low-frequency trigrams, no statistically significant advantage occurred for syllabic cues (.46 for syllabic cues vs. .44 for nonsyllabic cues). The same pattern of results was obtained when both types of cues were high-frequency trigrams (.43 for syllabic cues vs. .40 for nonsyllabic cues).

On the other hand, trigram frequency of the cues did affect performance. Letter clusters that occurred less often in the language were more effective cues for the word than were those that occurred more often in the language, as can be seen in the data for Sets 3 and 4. When syllabic cues had lower trigram frequencies than nonsyllabic cues (Set 3), a large advantage was obtained for the syllabic cues (.66 vs. .41). When nonsyllabic cues had lower trigram frequencies than syllabic cues (Set 4), an advantage occurred for nonsyllabic cues (.53 vs. .41). A similar effect was not observed between Set 1 items (low-frequency syllabic cues and nonsyllabic cues) and Set 2 items (high-frequency syllabic and nonsyllabic cues). However, the comparison between Set 1 and Set 2 items is not as relevant to the hypothesis being tested because different items and different semantic cues occurred in the two sets. Thus, any difference or, as in the present case, lack of difference is open to multiple interpretations. The data from Sets 3 and 4 are cleaner because each item served as its own control and the same semantic cue was used with the different low- or high-frequency letter cues. The data from Sets 3 and 4 show that trigram frequency, and not syllabicity, affects the retrieval of words in the crossword-puzzle paradigm.

These observations were confirmed by a repeated measures analysis of variance (ANOVA). The main effect of set type was reliable by subjects [$F(3,93) = 8.12$, $MS_e = .02$, $p < .01$], but the critical comparison between Set 1 items (low-frequency trigrams) and Set 2 items (high-frequency trigrams) only approached significance [$t(31) = 1.82$, $p < .08$]. The main effect of syllabic status was not reliable either by subjects [$F(1,31) = 2.87$, $MS_e = .04$, $p > .10$] or by items [$F(1,19) = 2.85$, $MS_e = .03$, $p > .10$]. The interaction between set type and syllabic status was reliable both by subjects [$F(3,93) = 17.62$, $MS_e = .02$, $p < .01$] and by items [$F(3,57) = 9.17$, $MS_e = .03$, $p < .01$].

Separate t tests were conducted for each group both by subjects and by items, and the results appear in Table 2. As shown there, the advantage of low-frequency syllabic cues over high-frequency nonsyllabic cues was reliable both by subject [$t(31) = 4.85$, $SE = .05$, $p < .01$] and by item analyses [$t(19) = 5.54$, $SE = .05$, $p < .01$]. The advantage of low-frequency nonsyllabic cues over syllabic cues was reliable by subject analysis [$t(31) = -2.85$, $SE = .04$, $p < .01$] and approached significance by item analysis [$t(19) = -1.93$, $SE = .06$, $p < .07$]. No other differences were reliable (ts < 1).

We also analyzed the latency data as Goldblum and Frost (1988) had done to see if syllabic cues aid retrieval of words relative to nonsyllabic cues. Mean latencies for

Table 2
Proportion of Fragments Correctly Completed in Experiment 1 for the Four Sets of Items as a Function of Different Trigram Frequencies of the Syllabic and Nonsyllabic Fragments; *t* Values for the Differences Between Syllabic and Nonsyllabic Cues in Each Set Are Also Reported by Subjects and by Items

Cue Types	Set 1 LF Syllabic LF Nonsyllabic	Set 2 HF Syllabic HF Nonsyllabic	Set 3 LF Syllabic HF Nonsyllabic	Set 4 HF Syllabic LF Nonsyllabic
Syllabic cues	0.46	0.43	0.66	0.41
Nonsyllabic cues	0.44	0.40	0.41	0.53
Syllabic advantage	+0.02	+0.03	+0.25	−0.12
Subjects: $t(31)$	0.55	0.84	4.85*	−2.85*
Items: $t(19)$	0.38	0.60	5.54*	−1.93

Note—LF = low frequency; HF = high frequency. *$p < .05$.

Table 3
Mean Latencies to Complete the Fragments (in Seconds) for the Four Sets of Items as a Function of Different Trigram Frequencies of the Syllabic and Nonsyllabic Fragments; *t* Values for the Differences Between Syllabic and Nonsyllabic Cues in Each Set are Also Reported by Subjects and by Items

Cue Types	Set 1 LF Syllabic LF Nonsyllabic	Set 2 HF Syllabic HF Nonsyllabic	Set 3 LF Syllabic HF Nonsyllabic	Set 4 HF Syllabic LF Nonsyllabic
Syllabic cues	7.0	7.0	5.9	7.9
Nonsyllabic cues	7.7	8.9	8.0	7.0
Syllabic advantage	+0.7	+1.9	+2.1	−0.9
Subjects: *t*	0.98	1.90	3.16*	−1.68
df	30	30	30	28
Items: *t*	0.80	1.92	2.96*	−0.88
df	19	19	18	16

Note—LF = low frequency; HF = high frequency. $^*p < .05$.

the syllabic and nonsyllabic conditions for the four item sets are presented in Table 3. Because of missing observations, only 28 observations could be included in the analysis by subjects and only 17 observations could be included in the analysis by items. Repeated measures ANOVAs indicated a reliable main effect of syllabic status [$F(1,27) = 6.14$, $MS_e = 6.89$, $p < .05$, by subjects, and $F(1,16) = 7.82$, $MS_e = 5.02$, $p < .05$, by items]. The interaction between syllabic status and set type was also reliable [$F(3,81) = 5.38$, $MS_e = 4.67$, $p < .01$, by subjects, and $F(3,48) = 3.63$, $MS_e = 4.36$, $p < .05$, by items].

However, planned comparisons between the syllable and nonsyllable conditions for each set type indicated that the only reliable difference was obtained in Set 3, where, for the fragments completed, the low-frequency syllables allowed faster completion of word fragments than did the high-frequency nonsyllables (see Table 3 for *t*s). This advantage was reliable both by subjects [$t(30) = 3.16$, $SE = 587.5$, $p < .01$] and by items [$t(19) = 2.96$, $SE = 812.7$, $p < .01$]. The advantage for syllables over nonsyllables in Set 2 approached significance [$t(30) = 1.9$, $SE = 805.74$, $p < .07$, by subjects, and $t(18) = 1.92$, $SE = 584.08$, $p < .07$, by items], but no other comparisons were reliable. To our surprise, the latency data did not reveal any systematic effects of either trigram frequency or syllabicity. We failed to obtain the predicted advantage in latency for letter cues of low trigram frequency in one of two conditions (low-frequency nonsyllabic/high-frequency syllabic cues condition). We also failed to obtain the predicted advantage for syllables in two of four conditions (low-frequency syllabic and nonsyllabic cues condition, and high-frequency syllabic cues, low-frequency nonsyllabic cues condition). While Goldblum and Frost (1988) had obtained large differences in latencies between their syllable and nonsyllable conditions (between 4.8 and 7.4 sec), we obtained much smaller differences (between 0.9 and 2.1 sec). We have no explanation for this discrepancy, but the data do not reveal any systematic effects of either trigram frequency or syllabicity. As a result, we emphasize the data obtained with proportion correct as the dependent measure.

To summarize the results of Experiment 1, we failed to replicate the consistent advantage that Goldblum and Frost (1988) observed for syllabic cues over nonsyllabic cues when we used a different (and a stricter) control for the effects of orthographic redundancy by equating trigram frequency for the syllabic and nonsyllabic cues on an item-by-item basis. The only hint of a syllabic advantage was in the latency data, which were discussed earlier. There was also some evidence for the role of syllables in the proportion-completed data in that there was a greater advantage for syllabic cues in Set 3 (.25) relative to the advantage for nonsyllabic cues in Set 4 (.12). However, we shall see that this finding was not replicated in Experiment 2, which suggests that syllabicity of letter cues probably plays a minor role in the completion of fragmented words. On the other hand, orthographic properties of letter cues (trigram frequency) seemed to be the important variable in mediating word retrieval in this task. Letter cues with lower trigram frequency were more effective than were letter cues of high trigram frequency when both types of cues were drawn from the same word (Sets 3 and 4). In summary, the data from Experiment 1 suggest little evidence that syllables play an important role in the retrieval of words from the mental lexicon. Before making this claim, however, we sought to replicate these findings in Experiment 2 with another group of subjects. We also wanted to examine whether similar results would be obtained in a paradigm in which subjects had previously studied the target words, as has been previously studied by others.

Dolinsky (1973) studied the role of syllables in an explicit-memory task by presenting subjects with words to recall (e.g., *influence*) and then cuing them with three letter cues that were either at the beginning, middle, or end of the word (e.g., INF_ _ _ _ _ _, _ _ _LUE_ _ _, or _ _ _ _ _ _NCE). Subjects were instructed to use the cues to recall the studied items. In one set of cuing conditions, the letter cues corresponded to the syllables of the word (e.g., sta-tis-tic), while in another set, they did not (e.g., inf-lue-nce, where the correct syllabic breakup would be in-flu-ence). Dolinsky (1973) found a strong effect for position such that letter cues at the beginning or end of a word were more effective than were letters in the middle positions. No advantage occurred for syllables in the beginning or end positions, but syllables were more effective cues than were nonsyllables in the middle positions of the word.

Dolinsky (1973) concluded that syllabic cues are more effective than are nonsyllabic cues in retrieving memorized words, but only when other more powerful variables (such as position of the letter cue in the word) could not exert an influence. We wanted to examine whether the same pattern would be observed in an implicit-memory task (Graf & Schacter, 1985) when we compared the relative roles of orthographic properties and syllabicity of letter cues.

In implicit-memory tasks, subjects are typically presented with a set of words in a study phase and then during a later test phase, they are simply asked to complete a set of studied and nonstudied word fragments with the first word that comes to mind (Roediger, 1990; Schacter, 1987). The task is said to be implicit because subjects are not asked to recall items from the list to the cues, as in Dolinsky's (1973) experiment. Bolstering this conclusion, Graf and Mandler (1984), among others, have shown that dissociations can occur when only instructions (implicit or explicit) are varied when people are given parts of words as cues during testing. Priming is measured by the extent to which performance is facilitated when the items have been studied relative to when they have not been studied. On the basis of the results of Experiment 1, we predicted that an advantage would be obtained for letter cues with low trigram frequency on the primed items. Assuming Dolinsky's (1973) conclusions extend to the priming domain, we also predicted an advantage for syllabic cues relative to nonsyllabic cues when their trigram frequency could not facilitate performance on the task (that is, when letter cues had a high trigram frequency). For nonstudied items, we expected to replicate the results of Experiment 1.

EXPERIMENT 2

Method

Subjects. Fifty-six Rice University undergraduates participated in this experiment in partial fulfillment of a course requirement.

Materials and Design. The materials used in this experiment were the same as those used in Experiment 1. The design was similar to that of Experiment 1 except that half of the targets in the syllabic and nonsyllabic conditions in each of the four sets were presented in the study list before the fragment-completion test was administered. There were four study lists to counterbalance the studied and nonstudied items across lists and two test lists to counterbalance the syllabic and nonsyllabic conditions. Every item appeared in each of the four combinations (studied–nonstudied/syllabic–nonsyllabic) equally often.

The dependent measure used in this experiment was the proportion of fragments completed successfully. Response latency was not used as a dependent measure in this experiment because the design resulted in too few observations per subject per condition to provide stable measures of response time.

Procedure. The subjects were tested in groups of 2 to 7. In the study phase, they rated 40 words for pleasantness of meaning along a scale from 1 to 7, with 1 representing unpleasant and 7 representing pleasant in meaning, at the rate of 5 sec per item. The subjects were paced by an experimenter. The words were presented to the subjects in study booklets with several words per page. Each subject was provided with a cover sheet so that he/she revealed each item only for 5 sec. Next was a 5-min distractor task in which the subjects recalled the names of as many U.S. Presidents as possible. This activity was followed by a test phase in which the subjects were asked to solve 80 word fragments (40 studied and 40 nonstudied) using both the semantic and letter cues that were provided to them on a test booklet. No mention was made of the relation between the earlier study phase and the word-fragment-completion task. The subjects were allowed a maximum of 15 sec per item. They were asked to use a blank sheet to uncover each item in the list. They were also instructed not to work on previous items. The experimenter paced the group through the task. The study–test session lasted approximately 1 h.

Results and Discussion

Table 4 shows the proportion of items correctly completed as a function of syllabic or nonsyllabic cues in the nonstudied or studied conditions. Examine first the nonstudied items, where we replicated the findings of Experiment 1. Once again, little or no difference occurred between syllabic and nonsyllabic cues when the trigram frequencies were equated for the two types of cues at the

Table 4
Proportion of Fragments Correctly Completed for the Nonstudied and Studied Items in Experiment 2 for the Four Sets of Items as a Function of Syllabic and Nonsyllabic Cues; *t* Values are Also Reported for the Difference Between Syllabic and Nonsyllabic Cues by Subjects and by Items

Cue Types	Set 1 LF Syllabic LF Nonsyllabic	Set 2 HF Syllabic HF Nonsyllabic	Set 3 LF Syllabic HF Nonsyllabic	Set 4 HF Syllabic LF Nonsyllabic
		Nonstudied Items		
Syllabic cues	0.53	0.42	0.73	0.39
Nonsyllabic cues	0.47	0.43	0.45	0.63
Syllabic advantage	+0.06	−0.01	+0.28	−0.24
Subjects: $t(55)$	1.54	−0.18	7.20*	−5.60*
Items: $t(19)$	1.29	−0.14	5.63*	−5.32*
		Studied Items		
Syllabic cues	0.70	0.67	0.89	0.70
Nonsyllabic cues	0.66	0.56	0.67	0.74
Syllabic advantage	+0.04	+0.11	+0.22	−0.04
Subjects: $t(55)$	1.09	2.26*	5.73*	−0.93
Items: $t(19)$	1.10	2.24*	3.24*	−1.05

*$p < .05$.

low trigram frequency values (.53 for syllabic cues vs. .47 for nonsyllabic cues) or high trigram frequency values (.42 for syllabic cues and .43 for nonsyllabic cues). However, trigram frequency of the letter cues affected the completion of fragmented words. Letter cues with low trigram frequency resulted in better performance than did letter cues with high trigram frequency. Thus, when syllabic cues had lower trigram frequencies than did nonsyllabic cues in Set 3, a syllabic advantage was observed (.73 vs. .45), but when nonsyllabic cues had lower frequencies than did syllabic cues, the difference was reversed (.39 for syllabic cues and .63 for nonsyllabic cues). Unlike the results in Experiment 1, the syllabic advantage in Set 3 was equivalent in magnitude to the nonsyllabic advantage in Set 4 (.28 vs. .24).

The pattern of results for the studied items was somewhat different. Now, both syllabicity and trigram frequency determined performance on the task. When trigram frequencies of both types of cues were low (Set 1), little or no syllabic advantage was obtained (.70 for syllabic cues, .66 for nonsyllabic cues). When syllabic cues were lower in trigram frequency than were the nonsyllabic cues (Set 3), a syllabic advantage was found (.89 vs. .67). So far, the results with the studied items appear to be similar to those found with the nonstudied items.

The interesting results occurred in the other two conditions where (presumably) low trigram frequency did not facilitate performance (Sets 2 and 4). When both syllabic and nonsyllabic cues had high trigram frequencies (Set 2), an advantage was obtained for the syllabic cues (.67 vs. .56). Similarly, when syllabic cues had high trigram frequencies relative to the nonsyllabic cues (Set 4), the effects of syllabicity and low trigram frequency appeared to cancel out one another (.70 for syllabic fragments vs. .74 for nonsyllabic fragments).

Of course, the priming data are difficult to interpret in Sets 3 and 4 because performance on the nonstudied items was different for syllabic and nonsyllabic cues. The amount of possible priming is greatly constrained in various conditions in these sets because of high nonstudied base rates. Two examples are in the nonstudied conditions for the low-frequency syllabic cues in Set 3 and the low-frequency nonsyllabic cues in Set 4. Such high base rates may reduce the magnitude of priming in these conditions more than in the high-frequency nonsyllabic condition in Set 3 and the high-frequency syllabic condition in Set 4, respectively. In other words, the differences in performance between syllabic and nonsyllabic cues in the nonstudied conditions should attenuate the syllabic advantage for the studied items in Set 3 and diminish the nonsyllabic advantage in Set 4. The data indicate that this decrease in the nonsyllabic advantage did occur in Set 4. However, since no corresponding decrease occurred for the syllabic advantage in Set 3, we attribute the decreased nonsyllabic advantage in Set 4 to the effects of syllabicity. In summary, syllabic cues facilitated retrieval of words on the memory task when the letter cues were also high on trigram frequency and thus could not facilitate performance. These data provide support for Dolinsky's (1973) conclusions that syllables serve as effective cues when other powerful variables such as position of the letter cue (or in our case, trigram frequency) do not influence performance.

These observations were confirmed by repeated measures ANOVAs. The critical three-way interaction between study status, syllabic status, and set type was reliable by subjects and by items [$F(3,165) = 5.75$, $MS_e = .04$, $p < .01$, by subjects, and $F(3,76) = 6.47$, $MS_e = .01$, $p < .01$, by items], which indicates that the differences between syllabic cues and nonsyllabic cues for the four item groups were different for studied and nonstudied items. The two-way interaction between syllabic status and set type was also reliable by subjects and by items [$F(3,165) = 27.33$, $MS_e = .05$, $p < .01$, by subjects, and $F(3,76) = 14.22$, $MS_e = .04$, $p < .01$, by items], which indicates that the differences between syllabic and nonsyllabic cues were different for the four item groups.

Planned comparisons between syllabic and nonsyllabic cues on the nonstudied items revealed an advantage for nonstudied low-frequency syllabic cues over nonstudied high-frequency nonsyllabic cues. This effect was reliable both by subject [$t(55) = 7.20$, $SE = .04$, $p < .01$] and by item analyses [$t(19) = 5.63$, $SE = .05$, $p < .01$]. The advantage for nonstudied low-frequency nonsyllabic cues over nonstudied high-frequency syllabic cues was also reliable both by subject [$t(55) = -5.60$, $SE = .04$, $p < .01$] and by item analyses [$t(19) = -5.32$, $SE = .05$, $p < .01$]. No other differences were reliable ($p > .10$). These results with the nonstudied items mirror the results of Experiment 1 in suggesting that orthographic properties of words such as trigram frequency are important in the retrieval of words while phonological properties such as syllabicity appear to have little effect.

For studied items, *t* tests revealed an advantage for studied syllabic fragments over studied nonsyllabic fragments when they both had high trigram frequency. This effect was reliable both by subject [$t(55) = 2.26$, $SE = .04$, $p < .05$] and by item analyses [$t(19) = 2.24$, $SE = .04$, $p < .05$]. The advantage for studied low-frequency syllabic cues over studied high-frequency nonsyllabic cues was also reliable both by subject [$t(55) = 5.73$, $SE = .04$, $p < .01$] and by item analyses [$t(19) = 3.24$, $SE = .07$, $p < .01$]. No other differences approached significance ($ps > .10$).

The results of Experiment 2 suggest that orthographic properties of word structure such as trigram frequency are more important in the retrieval of words than are phonological properties such as syllabicity. This conclusion is similar to conclusions drawn by some in the literature on visual word recognition (e.g., Seidenberg, 1987). However, on tasks requiring retrieval from memory, both syllabicity and trigram frequency appear to influence performance. Performance on the memory task was facilitated when the letter cues of studied items were low in trigram frequency (and thus specified the studied word more completely). However, when the letter cues were high in trigram frequency (and did not specify the studied item), letter cues that were syllables facilitated performance better than did letter cues that were not syllables. This result is consistent with Dolinsky's (1973) conclusions that syllables influence memory performance only when other, more important variables such as letter-cue position (in Dolinsky's experiment) or trigram frequency (in our experiment) do not influence performance. Interestingly, his conclusions also extend to an implicit-memory paradigm.

GENERAL DISCUSSION

Two main findings emerged from these experiments. First, there was little evidence to suggest that syllables play an important role in the representation of words in the mental lexicon. Syllables did facilitate performance in the crossword-puzzle-solving task, but the effect was restricted to specific conditions. Second, orthographic properties (as measured by trigram frequency in these experiments) did influence the retrieval of words from their fragments. Specifically, letter cues with low trigram frequency resulted in better performance than did letter cues with high trigram frequency. We discuss each of these findings separately, along with the implications of these results for theories of lexical representation.

The finding that syllabic cues did not consistently facilitate the completion of fragmented words relative to nonsyllabic cues was surprising to us because we had expected to replicate the Goldblum and Frost (1988) results, at least under conditions when syllabic and nonsyllabic cues were equated for trigram frequency. The discrepancy in their results on the one hand, and Seidenberg's (1987) and our results on the other, may be accounted for by the different types of controls used in the experiments. Goldblum and Frost controlled for the effects of orthographic properties by equating the "syllable" and "nonsyllable" conditions for their respective mean trigram frequencies. On the other hand, in both Seidenberg's and our studies, this control was achieved by matching the words or cues that appeared in the "syllable" and "nonsyllable" conditions for their orthographic properties on an item-by-item basis. Thus, in Seidenberg's experiments, each word in the syllable condition (e.g., *naive*) had a corresponding word in the nonsyllable condition (e.g., *waive*) that was orthographically similar. In our experiment, each cue word in the syllable condition (e.g., NOL in *technology*) had a corresponding cue word in the nonsyllable condition (e.g., HNO) that had approximately the same trigram frequency. This implies that Goldblum and Frost (1988) obtained an advantage for syllabic cues because they used low-frequency syllabic cues and high-frequency nonsyllabic cues. An examination of their material indicates that this was not the case. Then how can we reconcile their findings with ours?

There were two other differences between the Goldblum and Frost (1988) study and our study that we believe could account for the discrepancy. First, Goldblum and Frost used syllabic cues that occurred in the first, middle, and final positions of the word, whereas their nonsyllabic cues in the unpronounceable condition were always drawn from the middle positions. Although Goldblum and Frost did try to control for position effects by comparing cues drawn only from the same position, this probably resulted in comparisons of syllabic and nonsyllabic fragments drawn from different words. In our study, both syllabic and nonsyllabic cues were always drawn from the middle positions in the word. Second, Goldblum and Frost used the same fragment as a cue for several words in the same condition (e.g., NSI was used to cue *dimension*, *defensive*, and *intensive* in the unpronounceable nonsyllables condition). In our study, a fragment served as a cue only once. We believe that our failure to replicate Goldblum and Frost's findings is probably a result of these stricter (and more appropriate) controls.

The main finding in these experiments was that orthographic properties of words that are sometimes correlated with syllables play an important role in the retrieval of words. The data confirm a conclusion reached by some researchers in the area of visual word recognition (e.g., Seidenberg, 1987; Taylor et al., 1977)—multiletter clusters that may or may not be syllables in a word sometimes act as the sublexical units in a word. But what cluster of letters constitutes the sublexical units in a word?

Seidenberg (1987) suggests that in a system that recognizes words by exploiting orthographic redundancy information, letters that co-occur frequently in words may act as the sublexical units in visual word recognition. For instance, in his experiments, the letter cluster IVE, which functioned as a perceptual unit in *naive* and *waive*, has a trigram frequency of 497 (Underwood & Schulz, 1960), but the letter cluster preceding it (AIV) has a trigram frequency of 2. The results from our experiments indicate the opposite finding—that low-frequency letter clusters act as sublexical units in the retrieval of words. Although these results appear to contradict Seidenberg's findings, we believe that the results are similar in that they emphasize orthographic rather than phonological properties of words as being the crucial variables in word recognition and retrieval. In tasks requiring the rapid recognition of words, such as lexical decision, word naming, or tachistoscopic recognition of words, orthographic redundancy in letter patterns may be exploited to achieve fast and accurate recognition of the words. Letter patterns that co-occur less frequently in the language may be processed more slowly because they lack the redundancy that is present in high-frequency letter patterns. Hunt and Toth (1990) have found some evidence in support of this hypothesis. In their experiments, they found that lexical decisions to orthographically distinct words such as *sphinx* were slower than were lexical decisions to orthographically common words such as *eraser*. Similarly, tachistoscopic identification of orthographically distinct words was poor relative to the identification of orthographically common words.

On the other hand, in tasks requiring the retrieval of words from a mental lexicon or from memory, performance may be benefited by infrequent letter patterns because they specify the words more completely than do frequent letter patterns. Although our study is the first one to explore this hypothesis, we can point to other similar findings in the memory domain. For instance, Nelson, Canas, Bajo, and Keelan (1987) found that word fragments with large numbers of potential targets (e.g., _INE) are less effective cues to retrieve a studied word (*vine*) than are word fragments with small numbers of potential targets (_OOD for *wood*). This pattern was observed even when the cues and targets were equated for preexperimental strength, that is, _INE was as likely to elicit *vine* as _OOD was to elicit *wood*. Similarly, Hunt and Toth (1990) observed that word fragments of studied orthographically distinct words (e.g., *calypso*) were more likely to be completed than word fragments of studied orthographically common words (e.g., *mentor*). Hunt and Toth did not find this effect for the nonstudied items, but they used a random selection of nonadjacent letters as cues on their task and this makes it difficult to compare their findings with our data.

In summary, both our data and previous research indicate that orthographic properties of words are important in mediating access to words. Syllables do not appear to play a significant role in mediating this access to words. What are the implications of these findings for models of lexical representation?

These data do not support models of word recognition that suppose that syllables form an important role in the representation of words in the mental lexicon (e.g., Spoehr & Smith, 1973). Instead, our results suggest that models of lexical representation that are based on orthographic redundancy information account better for the data. One such model is the Seidenberg and McClelland (1989) model of visual word recognition and naming. In this model, only the implicit structure of English orthography and the regularity between orthography and phonology is encoded in a connectionist framework. Yet, the model simulates several important results in lexical decision and naming studies. While the present implementation of their model is restricted to simulating results in visual word recognition, we believe that their emphasis that orthographic redundancy information is critical for the representation of words in the mental lexicon is supported by our data.

REFERENCES

Adams, M. (1981). What good is orthographic redundancy? In H. Singer & O. J. L. Tzeng (Eds.), *Perception of print* (pp. 197-221). Hillsdale, NJ: Erlbaum.

Balota, D. A., & Chumbley, J. I. (1985). The locus of word frequency effects in the pronunciation task: Lexical access and/or production frequency? *Journal of Memory & Language*, **24**, 89-106.

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

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

Frederiksen, J. R., & Kroll, J. F. (1976). Spelling and sound: Approaches to the internal lexicon. *Journal of Experimental Psychology: Human Perception & Performance*, **2**, 361-379.

Goldblum, N., & Frost, R. (1988). The crossword puzzle paradigm: The effectiveness of different word fragments as cues for the retrieval of words. *Memory & Cognition*, **16**, 158-166.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning & Verbal Behavior*, **23**, 553-568.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **11**, 501-518.

Hansen, D., & Rodgers, T. S. (1968). An exploration of psycholinguistic units in initial reading. In K. S. Goodman (Ed.), *The psycholinguistic nature of the reading process* (pp. 59-102). Detroit: Wayne State University Press.

Henderson, L. (1985). Issues in the modelling of pronunciation assembly in normal reading. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 459-508). London: Erlbaum.

Hoard, J. (1971). Aspiration, tenseness and syllabification in English. *Language*, **47**, 133-140.

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

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

Hunt, R. R., & Toth, J. P. (1990). Perceptual identification, fragment completion, and free recall: Concepts and data. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **16**, 282-290.

Kahn, D. (1976). *Syllable-based generalizations in English phonology.* Bloomington: Indiana University Linguistics Club.

Klapp, S. T. (1971). Implicit speech inferred from response latencies in same-different decisions. *Journal of Experimental Psychology*, **91**, 262-267.

Klapp, S. T., Anderson, W. G., & Berrian, R. W. (1973). Implicit speech in reading reconsidered. *Journal of Experimental Psychology*, **100**, 368-374.

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

Lima, S. D., & Pollatsek, A. (1983). The Basic Orthographic Syllable Structure (BOSS) reconsidered: Lexical access via an orthographic code? *Journal of Verbal Learning & Verbal Behavior*, **22**, 310-332.

Mewhort, D. J. K., & Beal, A. L. (1977). Mechanisms of word identification. *Journal of Experimental Psychology: Human Perception & Performance*, **3**, 629-640.

Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. In D. Besner & G. W. Humphreys (Eds.), *Basic processes in reading: Visual word recognition* (pp. 264-336). Hillsdale, NJ: Erlbaum.

Neely, J. H., Crawley, E. J., & Vellutino, F. R. (1990, November). *Do words that are first syllables of other words access their semantic codes?* Paper presented at the 31st Annual Meeting of the Psychonomic Society, New Orleans.

Nelson, D. L., Canas, J. J., Bajo, M. T., & Keelan, P. D. (1987). Comparing word fragment completion and cued recall with letter cues. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **13**, 542-552.

Oxford American Dictionary (1980). New York: Oxford University Press.

Pratt, F. (1939). *Secret and urgent*. Indianapolis: Bobbs-Merrill.

Prinzmetal, W., & Millis-Wright, M. (1984). Cognitive and linguistic factors affect visual feature integration. *Cognitive Psychology*, **16**, 305-340.

Prinzmetal, W., Treiman, R., & Rho, S. H. (1986). How to see a reading unit. *Journal of Memory & Language*, **25**, 461-475.

Richardson, J. T. E. (1976). The effects of stimulus attributes upon latency of word recognition. *British Journal of Psychology*, **67**, 315-325.

Roediger, H. L. (1990). Implicit memory: Retention without remembering. *American Psychologist*, **45**, 1043-1056.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **13**, 501-518.

Seidenberg, M. S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance: Vol. 12. Reading* (pp. 245-263). Hillsdale, NJ: Erlbaum.

Seidenberg, M. S. (1989). Reading complex words. In G. N. Carlson & M. K. Tanenhaus (Eds.), *Linguistic structure in language processing* (pp. 53-107). Dordrecht: Kluwer.

Seidenberg, M. S., & McClelland, J. I. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, **96**, 523-568.

Shulman, H. G., Hornak, R., & Sanders, E. (1978). The effects of graphemic, phonetic, and semantic relationships on access to lexical structures. *Memory & Cognition*, **6**, 115-123.

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

Spoehr, K., & Smith, E. (1975). The role of orthographic and phonotactic rules in perceiving letter patterns. *Journal of Experimental Psychology: Human Perception & Performance*, **1**, 21-34.

Taylor, G. A., Miller, T. J., & Juola, J. F. (1977). Isolating visual units in the perception of words and nonwords. *Perception & Psychophysics*, **21**, 377-386.

Treisman, A., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology*, **14**, 107-141.

Underwood, B. J., & Schulz, R. W. (1960). *Meaningfulness and verbal learning*. Chicago: Lippincott.

APPENDIX

Materials Used in Experiments 1 and 2

Items in each of the four sets of words are given with their syllabic breaks. The second column gives the syllabic letter cues used in the syllabic conditions, the third gives the nonsyllabic letter cues used in the nonsyllabic condition, and the final column gives the semantically related cue that was presented with the letter cues.

Set 1: Low-Frequency Syllabic Cues, Low-Frequency Nonsyllabic Cues

1.	ab.dom.inal	dom	bdo	pertaining to internal organs
2.	bur.gun.dy	gun	rgu	French wine
3.	in.hab.itant	hab	nha	tenant
4.	tech.nol.ogy	nol	hno	applied science
5.	ver.bos.ity	bos	rbo	wordiness
6.	thy.rox.ine	rox	yro	hormone
7.	de.fla.tion	fla	efl	flattening
8.	ex.hib.it	hib	xhi	present
9.	om.nip.otent	nip	mni	supreme
10.	ob.nox.ious	nox	bno	unpleasant
11.	qua.dru.pled	dru	adr	multiply
12.	re.vul.sion	vul	lsi	loathing
13.	sta.lag.mite	lag	gmi	geological formation
14.	ce.leb.rity	leb	ebr	dignitary
15.	hemo.glo.bin	glo	ogl	pigment in blood
16.	in.teg.rity	teg	egr	principle
17.	to.bog.gan	bog	ogg	sled
18.	an.nul.ment	nul	lme	nullify
19.	ag.nos.tic	nos	gno	skeptic
20.	mi.sog.ynist	sog	ogy	distrusts opposite sex

Set 2: High-Frequency Syllabic Cues, High-Frequency Nonsyllabic Cues

1.	con.gen.ial	gen	nge	sociable
2.	ad.ver.tise	ver	rti	publicize
3.	com.par.ative	par	omp	relative
4.	an.ces.tor	ces	nce	forefather
5.	be.wil.der	wil	lde	perplex
6.	di.rec.tive	rec	ect	order
7.	ex.pec.tation	pec	xpe	hope
8.	cy.lin.drical	lin	ind	geometric shape
9.	im.pos.tor	pos	ost	quack
10.	quin.tes.sence	tes	sse	epitome
11.	neces.sar.ily	sar	ssa	obligatorily
12.	non.sen.sical	sen	ons	meaningless
13.	con.tem.plate	tem	emp	ponder
14.	pre.cur.sor	cur	urs	forerunner
15.	vin.dic.tive	dic	ndi	venomous

16.	tran.sis.tor	sis	ans	electronic device
17.	dis.tor.tion	tor	ort	misleading
18.	bad.min.ton	min	adm	game
19.	con.den.sation	den	ond	compression
20.	en.tan.gle	tan	ang	intertwined

Set 3: Low-Frequency Syllabic Cues, High-Frequency Nonsyllabic Cues

1.	con.vey.or	vey	nve	moving belt
2.	an.noy.ance	noy	nno	irritation
3.	in.sip.id	sip	nsi	tasteless
4.	kid.nap.per	nap	ppe	abductor
5.	gym.nas.tics	nas	ast	exercises
6.	clair.voy.ance	voy	anc	psychic power
7.	cu.cum.ber	cum	umb	vegetable
8.	anti.cli.max	cli	icl	letdown
9.	an.tiq.uity	tiq	nti	ancient times
10.	archi.tec.ture	tec	ctu	structural design
11.	vis.cos.ity	cos	isc	stickiness
12.	e.nun.ciate	nun	unc	speak
13.	hori.zon.tal	zon	ont	flat
14.	di.vor.cee	vor	rce	estranged woman
15.	raga.muf.fin	muf	ffi	tramp
16.	ther.mom.eter	mom	erm	measuring device
17.	ren.dez.vous	dez	nde	meeting
18.	ef.fem.inate	fem	ffe	unmanly
19.	re.dun.dant	dun	und	superfluous
20.	con.tex.tual	tex	nte	relevant

Set 4: High-Frequency Syllabic Cues, Low-Frequency Nonsyllabic Cues

1.	ob.sta.cle	sta	acl	hindrance
2.	ni.tro.gen	tro	itr	gas
3.	vol.can.ic	can	lca	explosive
4.	at.mos.pheric	mos	tmo	related to air
5.	bas.ket.ball	ket	tba	sport
6.	car.pen.ter	pen	rpe	occupation
7.	chim.pan.zee	pan	nze	animal
8.	ex.ten.sion	ten	xte	continuation
9.	mi.cro.scope	cro	icr	laboratory instrument
10.	mozza.rel.la	rel	zza	a type of cheese
11.	mul.ber.ry	ber	lbe	fruit
12.	nu.tri.ent	tri	utr	e.g., vitamin
13.	com.bus.tible	bus	mbu	inflammable
14.	pa.pri.ka	pri	apr	condiment
15.	pa.ral.ysis	ral	ysi	numbness
16.	hypo.der.mic	der	ypo	under the skin
17.	dis.tur.bance	tur	rba	uproar
18.	dis.tin.guish	tin	ngu	classify
19.	ad.mon.ish	mon	dmo	reprimand
20.	remi.nis.cence	nis	sce	nostalgia

(Manuscript received May 28, 1991;
revision accepted for publication December 6, 1991.)