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# The Differential Role of Syllabic Structure in Stem Completion for French and English

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Four experiments were carried out to examine the role of a word's internal structure (i.e. syllables) in stem completion for French and English speakers. Subjects studied a series of unrelated words, selected so that two words shared their initial consonant-vowel-consonant (CVC) segment (e.g. BALANCE–BALCON). Subjects were then presented with CV or CVC stems (e.g. BA or BAL), half of which corresponded to the studied words' initial segment, and were asked to produce the first word that came to mind. Half the subjects performed the entire task in the auditory modality, half did so in the visual modality (Experiment 1). In both modalities, French subjects completed the stems more often with studied words in which the initial syllable matched the stem structure (e.g. BALCON for BAL) than with studied words that did not match (e.g. BALANCE for BAL). These syllabic effects were dissociable from explicit memory (Experiment 2) and appear to be language-specific, since they were obtained with French speakers but not with English speakers (Experiments 3 and 4). The results are highly consistent with the notion that implicit memory for words reflects the operations of perceptual phonological representations which are organised differently in French and English.

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## INTRODUCTION

The stem completion task has recently become a standard tool in memory research. In this task, subjects typically first study a set of words, such as DEFEND. Later, they complete a series of non-studied and studied word stems (such as DEF) with the first word that comes to mind (see Graf, Mandler, & Haden, 1982; Warrington & Weiskrantz, 1970). The task is considered an implicit memory task because subjects are not required to intentionally retrieve words from the list, as in a standard cued-recall task. Implicit memory is measured by the extent to which performance is biased towards the words studied relative to those that have not been studied. Such facilitation by prior experience is termed "priming".

The stem completion task owes its wide use to the explosion of research activities on implicit memory that has taken place over the last decade. This research productivity is primarily motivated by the need to specify the nature of the processes that underlie implicit memory. According to the theories that provided the initial impetus for the present study (Moscovitch, 1992; Tulving & Schacter, 1990), implicit memory effects reflect, to a large extent, the operations of a perceptual representation system (PRS) that functions independently of the episodic or declarative memory system which supports explicit memory. The PRS refers to a class of domain-specific systems that process and represent information about the form and structure of the stimulus, but not its meaning or other associative properties. The construct of the PRS for words is largely consistent with most models of word recognition in which some kind of matching process between the perceptual input and a form-based lexical representation is posited. In recent years, much research has focused on the details of this matching process. The present study was driven by these recent developments.

The aim of the present set of experiments was to examine the notion that implicit memory effects in stem completion have a lexical (or pre-lexical) origin by exploiting current ideas on how speech is perceptually organised. We thus adopted a research strategy that exploits cross-domain hypothesis testing (Schacter, 1992), by evaluating concepts and findings about implicit memory in domains other than the ones in which the hypotheses were originally formulated. Neuropsychological studies of amnesic patients have provided the primary data for theories of implicit memory (see Shimamura, 1986, for a review). In the present study, we explore a new avenue, that of speech perception.

Before describing the relevant literature in the speech perception domain, it is useful first to review the evidence that has led to the proposal that (pre)lexical processes subservise implicit memory effects in word stem completion tasks. Since most research has focused on visual

paradigms and processes, the current evidence is mostly limited to the operation of the PRS in the visual domain. Despite this visual bias in the literature, the few studies that have been done in the auditory modality suggest that the visual and auditory PRS subsystems operate along similar principles. Therefore, the results obtained in each modality will be treated jointly in what follows, unless specified otherwise.

One line of evidence arguing for the perceptual origin of stem completion with studied words is that the task is not sensitive to the kind of elaborative processing that usually improves (explicit) memory (e.g. Bowers & Schacter, 1990; Graf & Mandler, 1984). For instance, having subjects judge the pleasantness of words has no effect on the subsequent completion of the stems of these words. In contrast, pleasantness judgments improve explicit recall of the presented word when cued with its initial segment (e.g. Schacter & Church, 1992). These findings suggest that stem completion depends on a processing system that does not represent the meaning of a word.

A second line of evidence is that stem completion is sensitive to the perceptual form of studied words. Changes in the structural aspects of the words between the study phase and the stem completion phase, such as those produced by a change in modality of presentation (i.e. from auditory presentation of the word to visual presentation of the stem), reduces the magnitude of the implicit memory effects (e.g. Bassili, Smith, & MacLeod, 1989; see Roediger & McDermott, 1993, for a review). Similarly, a surface change produced by transformations of typographic letter case (in visually presented words; Marsolek, Kosslyn, & Squire, 1992; Marsolek, Squire, Kosslyn, & Lulenski, 1994) or by a voice change (in auditory words; Church & Schacter, 1994; Schacter & Church, 1992) between study and test phase can have a detrimental effect on priming in stem completion tasks. The argument is that if the implicit memory effects are perpetually driven, then they should be considerably reduced when relevant perceptual attributes are changed between study and test. Such surface changes do not, however, abolish priming effects. Thus, word priming in stem completion is not entirely based on surface properties but reflects the operation of more abstract invariant phonological representations that do not include letter-specific or speaker-specific perceptual information (Church & Schacter, 1994; Marsolek et al., 1992, 1994; Schacter & Church, 1992). In each modality, the PRS is conceived as involving two subsystems, one that computes an abstract orthographic or phonological form and one that computes perceptually specific form representations. In the present study, we will be concerned mostly with the former subsystem, the abstract phonological word form subsystem (i.e. the lexicon) that seems to account for the largest part of the implicit memory effects obtained in stem completion (Schacter & Church, 1992).

The notion that stem completion is primarily mediated by phonological representations, even in the visual modality, has been demonstrated with rhyming words. Words that rhyme, such as HAIR, DARE and HEIR, will facilitate completion of the stem (e.g. CHA) with a rhyming word (e.g. CHAIR; Mandler, Graf, & Kraft, 1986). In contrast, presenting subjects with a set of conceptually (categorically) related words has no effect on stem completion. More recently, Mandler and his colleagues (Mandler, Hamson, & Dorfman, 1990) have reported some evidence for semantic priming effects on stem completion, but these effects are much weaker than the phonological priming effects. The only divergent data (Graf & Schacter, 1985) which suggest a role for conceptual mediation in stem completion have been difficult to replicate (Cermak, Bleich, & Blackford, 1988; Mayes & Gooding, 1989; Shimamura & Squire, 1989). Therefore, most results are consistent with the notion that word stem completion depends on a pre-semantic perceptual system that is akin to the phonological and orthographic lexical systems posited in speech perception and word reading, respectively.

If word stem completion does indeed reflect the operations of the (pre)lexical systems, then the task should demonstrate sensitivity to the same factors as those that are known to affect perceptual organisation of speech. One such factor is the differential nature of the speech segments that mediate lexical access in French and in English. French speakers rely on syllable segments to a greater extent than English speakers (Cutler, Mehler, Norris, & Segui, 1986; Mehler, Dommergues, Frauenfelder, & Segui, 1981). The primary evidence comes from studies employing a monitoring task. In this situation, subjects have to monitor a target [a consonant-vowel sequence (CV) or a consonant-vowel-consonant (CVC) sequence] in series of words. They are required to press a key whenever they hear the target at the beginning of words. For French speakers, responses are typically faster when the target corresponds exactly to the syllable of the word beginning. That is, subjects are faster to detect the target BA in the word BA·LANCE (a raised dot is used throughout to indicate a syllabic boundary), where it is a syllable, than in BAL·CON, where it is less than a syllable. Similarly, subjects are faster to detect the target BAL in BAL·CON, where it is a syllable, than in BA·LANCE, where it extends beyond the syllable boundary. If the listeners were using the phoneme for segmentation, they should have detected BA more quickly than BAL, irrespective of the type of word. This is because BA contains fewer phonemes than BAL. French monolinguals do not even use a phoneme-by-phoneme segmentation routine with English words. Even in this case, they show evidence of syllabification. In contrast, English speakers do not exhibit sensitivity to the syllabic structure in these situations. Tested with either English words or with the French

words that had elicited syllabic effects in French speakers, English speakers exhibit none of the effects that are indicative of the use of a syllabic procedure.

We posit that the differential role attributed to syllabic structure for French and English speakers, as shown by their performance on syllable monitoring tasks, should affect their performance on stem completion tasks. French speakers are expected to be sensitive to the syllabic correspondence between stems and words, whereas English speakers are not. The rationale is that lexical representations, which govern stem completion, contain the sublexical units that are used in speech perception. Lexical entries would therefore be arranged differently for French and English speakers, with a prominent role for the syllable for French speakers (e.g. Mehler, Dupoux, & Segui, 1990; Segui, Dupoux, & Mehler, 1990). Accordingly, the syllabic value of the stem provided for completion should influence word retrieval in French. For French speakers, the stem DEF for DE·FEND, as typically used in previous studies, is an odd case, for it violates the syllabic structure of the word. For French speakers, DEF might even constitute an obstacle for effective retrieval of the studied word DEFEND. In contrast, English speakers would not be sensitive to the syllabic match between the stem and the initial segment of the studied word. These predictions constitute the premises of the present study.

To assess these predictions, the design of the syllable-monitoring task used in speech perception research was applied to a primed stem completion task. This adaptation is facilitated by the fact that the syllable-monitoring task is, roughly, the mirror version of the stem completion task. Analogously, words were selected in pairs which shared the initial three phonemes, as in BALANCE and BALCON. The stems were of the CV or CVC type (e.g. BA and BAL). Assuming a common source for implicit memory effects and lexical organisation of speech entails that CV stems should elicit more cv-words (such as BA·LANCE) than cvc-words (such as BAL·CON), and vice versa for the CVC stems. We will refer to this pattern as the syllabic effect. French speakers were tested with these types of French stimuli in Experiments 1 and 2, and English speakers were tested with analogous English stimuli in Experiments 3 and 4.

The procedures used in all four experiments were similar in design to those used in previous stem completion studies.<sup>1</sup> In the study phase,

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<sup>1</sup>Subjects were presented with the words and stems either entirely in the auditory modality or in the visual modality. We examined stem completion in the two modalities because syllable-monitoring tasks are traditionally auditory, whereas stem completion tasks are traditionally visual (for rare exceptions, see Bassili, Smith, & MacLeod, 1989; Schacter & Church, 1992).

subjects name each word presented in isolation; the two words of each pair are randomly presented in the study list. In the test phase, subjects complete each stem orally with the first word that comes to mind. Among the stems, half correspond to the initial segment of the studied words. Stems are either of the CV or the CVC type. However, for each subject, only one stem (e.g. BA) is compatible with a studied word pair (e.g. BALANCE–BALCON) so that the word selected for completion will result from competition between the two studied words. The hypothesis is that if word selection is dictated by syllabic factors, then the word member of which the initial syllable matches the presented stem will be most likely selected. Alternatively, if completion is phonemically based, subjects should exhibit an effect of stem size. That is, subjects should provide more studied words in completing CVC stems than CV stems, without concern for the syllabic value of the initial word segment. The more phonemes the stem contains, the more information is provided about the studied words, hence facilitating their recovery.

## EXPERIMENT 1

In a previous study (Peretz, Lussier, & Béland, 1996), we found support for the existence of a syllabic effect in word stem completion by French speakers. In that study, subjects were tested either in the visual modality or in the auditory modality. The results reflected a syllabic match between the stem and the initial syllable of the word retrieved. That is, CVC stems elicited the production of *cvc*-words more often than *cv*-words, whereas CV stems yielded the opposite pattern or led to equal retrieval of both types of words. The syllabic matching procedure was found to be adopted in both the visual and the auditory modality, although it was found to be more reliable in the former. These initial findings require replication, however, because the syllabic structure for some studied words was different in each modality. There were target words that did not permit a one-to-one mapping between the phonological and the orthographic code, thus creating ambiguity with regard to syllable scoring. For example, the typographic rules dictate a bisection between the repeated consonants in the French word SYLLABE (i.e. SYL·LABE), thus producing a *cvc*-word, whereas the phonological rules yield a CVCV succession (i.e. SY·LLABE), hence producing a *cv*-word. Such ambiguities were removed from the present material and, therefore, this experiment represents a replication study with better controlled stimuli.

## Methods

*Subjects.* Forty university students served as experimental subjects on a voluntary basis. All were native speakers of French and came from the University of Montreal. They performed the stem completion task after having studied the word list. Eighty more subjects served as controls; they only performed the stem completion task.

*Stimuli.* Ten pairs of French words sharing the same initial three phonemes (CVC) were selected (see Appendix 1). In each pair, one member had a syllable boundary after the initial CVC (e.g. BAL·CON), whereas the other member had the syllable boundary after the initial CV (e.g. BA·LANCE). Syllable boundaries were defined following two principles. First, the universal unmarked syllable is CV (Kaye & Lowenstamm, 1985); therefore, in a  $C_1V_1C_2V_2$  sequence, the syllable boundary falls between  $V_1$  and  $C_2$ . Second, in a  $CVC_1C_2$  string, the syllable boundary is between  $C_1$  and  $C_2$  if  $C_1$  is more sonorous than  $C_2$ . The degree of sonority of a consonant was determined by the universal sonority scale (i.e. going from the less to the more sonorous are: stops, fricatives, nasals, l, r, w, y, u, i, o, e, a; Hooper, 1976; Kiparsky, 1979; Murray, 1987).

Care was taken to select initial segments that differed across the 10 word pairs and that permitted a one-to-one mapping between the phonological and the orthographic code. The members of the pairs were chosen so as to be comparable in terms of word frequency [from 0 to 13 per million, in Baudot, 1992;  $t(18) = 0.56$ ] and word length (all words were two-syllable words). Moreover, there had to be a minimum of 10 entries in the dictionary that began with the target CV or CVC sequence. Ensuring multiple completion possibilities allows one to measure the effects of prior exposure by computing the number of completions with the previously *presented words* versus those that correspond to *non-presented words*. It should be noted that word selection is highly limited by all these constraints, thus preventing the use of longer word lists.

For the completion task, the initial stems of the 20 presented words (10 of CV type and 10 of CVC type) were mixed with 20 filler stems that were similar in structure, but which did not appear in any of the study list items (e.g. GA and GAR; see Appendix 1).

*Procedure.* The experimental subjects were assigned randomly but in equal number to the auditory and visual modality condition. Each subject was presented with the same set of 20 words, one at a time in a random order. A different order was employed for each subject tested in the visual modality and two different orders were used for the subjects tested in the auditory modality. In the visual modality, each word was displayed

in lower case for 3 sec in the centre of the computer screen. Subjects were asked to read each word aloud. In the auditory modality, each word was spoken naturally with a neutral intonation and was presented every 3 sec through a loudspeaker and the subject was required to repeat it aloud. Subjects were informed that they should study the word list "for a later memory test". Explicit recall of the words was required at the end of the session. This feature of the design was included to meet subjects' expectations of a memory test and thus to make the implicit tests more believable as a filler task of "word generation" (see Craik, Moscovitch, & McDowd, 1994, for the use of a similar strategy).

In the stem completion task, 20 stems were presented one at a time, either visually or auditorily, in the same modality as the study phase. There were two series of 20 stems, each comprising 10 CV and 10 CVC stem types. In each series, half of the stems corresponded to the initial segments of the studied words and half did not, hence our reference to them as filler stems. Within a given stem series, only one stem type could cue both words of a studied pair. For example, only BA would cue the studied word pair BALANCE-BALCON in one series, and BAL would do so in the other series. Half the subjects were tested with the first series and half with the second series. Thus, each word of the study list was cued once with a CV stem and once with a CVC stem in a between-subjects design. For each stem, the subject was required to provide, as quickly as possible, the first word beginning with that segment which came to mind.

Presentation of the visual stimuli was controlled by the Psychlab program (Bub & Gum, 1987) operating a Macintosh microcomputer. Presentation of the auditory stimuli, which were read by a female French speaker and digitised on a Sony DAT recorder, was controlled by the same DAT apparatus.

The 80 control subjects performed the stem completion task without prior exposure to the word list. Half were tested in the auditory modality and half in the visual modality. They were required to provide the first word that came to mind as a completion of each stem. Their responses to the 20 stems, which corresponded to the words studied by the experimental subjects, were considered as baseline performance.

It should be noted that, in the stem completion task, both control and experimental subjects were expected to produce a large number of non-presented words, since the study list comprised low-frequency words and half the presented stems did not correspond to a studied word. These unprimed productions were analysed to examine the role of syllabic structure in lexical search in general.

Therefore, all responses, whether corresponding to presented or non-presented words, were classified using the criteria used to determine

syllabic boundaries in the presented words. That is, when possible, words were classified as cv-syllabified-words or cvc-syllabified-words. Not all words fall into these two categories. For example, words beginning with different syllabic structures, such as CVCC (like in FILM), or with a light diphthong CV<sub>1</sub>V<sub>2</sub> where V<sub>2</sub> is more sonorous than V<sub>1</sub> (like in CIEL), are excluded. Words that include the inter-consonantal mute vowel e (like in MATELOT pronounced MATLOT), or that end with a mute e (such as in CAGE), were considered ambiguous, because they yield different syllabification in the visual and auditory modalities (i.e. these words would be scored as cvc-words in the auditory modality and as cv-words in the visual modality). This duality has, in fact, been exploited and manipulated in another study (Peretz et al., 1996). Similarly, as noted above, geminates (double consonants such as in SYLLABE) also yield to different syllabification in the visual and auditory modality. All these cases were considered ambiguous with regard to the cv- versus cvc-word classification and were thus eliminated from the data. The elimination rate is specified below.

## Results

In the following, completion with presented words, which reflect the role of syllabic structure in (implicit) memory, will be distinguished from completion with non-presented words, which reflect the more general role of syllabic structure in lexical search.

*Presented Words.* To assess the role of syllabic structure in implicit memory, it is first necessary to assess its putative contribution to baseline performance. The number of target (i.e. presented) words produced by chance by the control subjects (i.e. without prior study of these words) was analysed using a 2 (visual vs auditory modality)  $\times$  2 (cv-word vs cvc-word)  $\times$  2 (CV vs CVC stem) analysis of variance with repeated measures on the last two factors. Despite the very few observations on which this analysis was performed (on 2.8% and 4.5% of words in the visual and auditory modality, respectively), the stem effect reached significance [ $F(1,78) = 14.56$ ,  $MSe = 0.07$ ,  $P < 0.001$ ]. This result indicates that, without prior exposure to the study list, more target words are produced after CVC than CV stems. There was, however, no significant interaction between stem and word [ $F(1,78) = 1.18$ ,  $MSe = 0.06$ , NS]. To assess the specific contribution of implicit memory, these baseline scores were subtracted from those obtained by each experimental subject. As can be seen in Fig. 1, where these baseline scores were subtracted from the scores of the experimental subjects, the subtracting procedure did not cancel priming effects for the studied words (otherwise the subtraction procedure

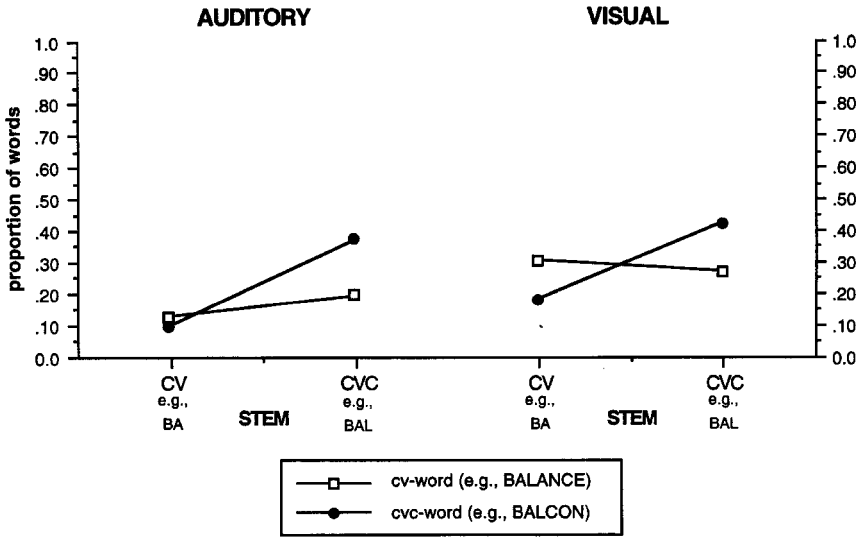
**PRESENTED WORDS**

FIG. 1. Mean proportion of *presented* words reported as a function of stem type and the structure of the word initial syllable in the auditory and visual modality, respectively, by French speakers in stem completion of Experiment 1. Baseline scores have been subtracted from the data.

would have produced scores close to zero). The priming effects are reliable at the 0.001 level. When the primed scores are compared to the baseline scores, the *t*-values ( $df = 58$ ) are 17.913 and 14.556 for the visual and auditory modality, respectively.

More importantly, the primed data are indicative of a syllabic effect in each modality. Experimental subjects more often produce studied words of which the initial syllable matches the structure of the stem. To achieve comparability with previous work, the data are presented in the figures analogous to those used with the syllable monitoring task (Cutler, Mehler, Norris, & Segui, 1986, 1989, 1992). The results summarised in Fig. 1 are depicted separately for each modality and are expressed as proportions, while the analyses were performed on raw scores corrected for guessing. Statistical assessment was carried out using an overall 2 (visual vs auditory modality)  $\times$  2 (cv-word vs cvc-word)  $\times$  2 (CV vs CVC stem) analysis of variance with repeated measures on the last two factors.

The presence of a syllabic effect was robust, since the stem  $\times$  word interaction was not only significant across the auditory and visual

modality [ $F(1,38) = 14.21$ ,  $MSe = 1.04$ ,  $P < 0.001$ ] but also in each modality [visual modality:  $F(1,19) = 10.82$ ,  $MSe = 0.89$ ,  $P < 0.005$ ; auditory modality:  $F(1,19) = 4.58$ ,  $MSe = 1.19$ ,  $P < 0.01$ ] The form of the interaction does not depend on whether the modality was visual or auditory, since the stem  $\times$  word  $\times$  modality interaction was far from significant ( $F < 1$ ). The response pattern is consistent with a syllabic effect because CVC stems elicited more cvc- than cv-words [with an advantage of 21%;  $t(39) = 3.206$ ,  $P < 0.01$ ] as completions, whereas CV stems tended to elicit more cv- than cvc-words [the advantage being 3% only;  $t(39) = 1.876$ ,  $P < 0.07$ ] as computed across modalities.

There was also an effect of stem size: Subjects generally provided more studied words when completing CVC stems than CV stems [ $F(1,38) = 30.94$ ,  $MSe = 0.60$ ,  $P < 0.001$ ]. Finally, subjects were found to produce more studied words in the visual than in the auditory modality [ $F(1,38) = 13.52$ ,  $MSe = 0.67$ ,  $P < 0.001$ ]. There were no other significant effects or interactions.

*Non-presented Words.* To examine whether the general strategy in word completion is to consider the stem as the word initial syllable, the experimental subjects' responses to the filler stems were examined. In addition, the control subjects' responses to all stems were analysed; in the latter, all responses that happened to correspond to the words studied by the experimental group were excluded, since these have already been taken into account in baseline performance.

In general, subjects produced more bisyllabic words (85 and 79% for the experimental and control group, respectively) than monosyllabic (4 and 3%), trisyllabic (9 and 15%) or still longer words (2 and 3%). More importantly, there was much variability in the types of completion. That is, although many completions consisted of the stem plus a CV syllable (39.6% of the experimental responses and 40.2% of the control responses), most productions did not. Many productions were either ambiguous with regard to the CV versus CVC categorisation (25 and 31%, following the criteria outlined above) or too variable to fall into a distinct category (comprising syllables of the type CCV, CVC, V, etc., and amounting to 35 and 28% of the data). This response distribution eliminates the possibility that subjects were completing the stems by merely producing cv-like completions, without regard to the syllabic value of the stem.

As previously mentioned, all the productions that could not be classified into cv-words versus cvc-words were eliminated; this amounted to 30% of all responses. Moreover, stems that were completed with a non-matching word (such as TABLE for PA) or a nonword (e.g. CHATIR), or with a word that strictly matched the stem (e.g. four  $\rightarrow$  FOUR), were

TABLE 1

Mean Proportions of Non-presented Words Provided by the Experimental and Control French-speaking Subjects as a Function of Stem Type and Word Category in Experiment 1

	<i>Stem</i>			
	<i>CV</i>		<i>CVC</i>	
	<i>cv-word</i>	<i>cvc-word</i>	<i>cv-word</i>	<i>cvc-word</i>
Experimental	0.59	0.13	0.09	0.59
Control	0.57	0.09	0.22	0.38

considered to be errors and thus were also eliminated. These types of error led us to reject a further 7.1% of the data; 280 and 1010 words, for the experimental and control group, respectively, remained for further analysis.

1. *Experimental subjects.* As can be seen in Table 1, the experimental subjects exhibited clear evidence of a syllabic effect in unprimed completion. This was supported by an analysis of variance. The interaction between stem and word was highly significant [ $F(1,38) = 241.86$ ,  $MSe = 0.95$ ,  $P < 0.001$ ]. CV stems cued cv-words more often than cvc-words [ $t(39) = 9.697$ ,  $P < 0.001$ ], whereas CVC stems cued cvc-words more often than cv-words [ $t(39) = 8.901$ ,  $P < 0.001$ ]. Since this pattern held for each modality, the latter factor was not included in the reported analysis. There was no effect of stem size ( $F < 1$ ).

2. *Control subjects.* As can be seen in Table 1, evidence for a robust syllabic effect was also observed in the controls' data. This was also supported by a highly significant stem  $\times$  word interaction [ $F(1,78) = 259.87$ ,  $MSe = 3.13$ ,  $P < 0.001$ ]. The advantage of cv-words over cvc-words when cued by CV stems was significant [ $t(79) = 18.268$ ,  $P < 0.001$ ] as was the advantage of cvc-words over cv-words when cued by CVC stems [ $t(79) = 5.734$ ,  $P < 0.001$ ]. This pattern also emerged in each modality and thus was not considered further. Interestingly, there was a significant effect of stem size [ $F(1,78) = 5.06$ ,  $MSe = 1.36$ ,  $P < 0.05$ ] but in the opposite direction to that observed on presented words. With non-target words, control subjects completed more CV stems than CVC stems.

## Discussion

As predicted, francophones were found to be highly sensitive to the syllabic value of the stem in completion performance. The results reflect a

syllabic match between the stem and the initial syllable of the word produced. That is, CVC stems elicit the production of cvc-words more often than cv-words, whereas CV stems yield the opposite pattern or lead to the equal production of both types of words. The syllabic match is present in both the visual and the auditory modality. However, consideration of a stem as word initial syllable is not specific to memory search, as it was found to apply to lexical search in general. That is, the use of this syllable-based procedure emerges for all words produced, whether or not primed by prior exposure. The fact that it did not emerge on baseline performance (i.e. on the few target words produced by control subjects without prior exposure) may be due to a floor effect.

It is worth mentioning that the strongest evidence for the use of a syllabic procedure in stem completion derives from the primed data. These scores reflect the selection of studied words that have been carefully matched in phonological structure and in frequency of usage. In contrast, completion with non-studied words is highly variable, and hence not rigorously controlled. Most word completions are not matched in terms of the initial  $C_1VC_2$  segments, since  $C_2$  is a free parameter for words produced after CV stems. However, the large database (i.e. above 1000 words) considered may compensate for this heterogeneity. Analysis of the internal structure of these produced words strongly suggests the use of a syllabic procedure in lexical retrieval in general, not just in memory-biased word retrieval. This finding is highly consistent with our premise that lexical access is constrained by syllabic organisation in French. At the same time, the fact that syllable matching occurs in all forms of word completion entails that implicit memory for the studied targets shows no specific influence due to the syllabic organisation of speech. The aim of Experiment 2 was to show that syllabification reflects the involvement of lexical representations, and not memory representations in general.

Another important aspect of this experiment is that the response pattern is compatible with the use of yet another speech unit—the phoneme—in word completion. This is reflected in the observation that CVC stems overall elicited more target words than CV stems. This effect (to which we refer as the “stem size effect”) can be related to the fact that CVC stems have more phonemes in common with the studied words than do CV stems. The greater phonemic overlap that exists between a CVC segment and the studied word pairs than between a CV segment and the studied words would confer an advantage to the CVC stems as primes for the studied words. The fact that a stem size effect also emerged on baseline performance, where word selection cannot be attributed to priming, undermines the interpretation of the stem size effect as evidence for the use of a phonemically based procedure.

The observation that CVC stems elicited more target words than CV stems even in the absence of prior study may be due to a set size effect rather than to the adoption of a phonemic strategy. Indeed, increasing the number of letters or sounds provided in stems systematically decreases the set of possible word candidates in a proportion of at least 3 to 1. For example, BA has 366 different lexical entries in the French dictionary (Petit Robert, 1991), whereas BAL corresponds to 71 of these entries. One direct consequence of this unbalanced number of word possibilities as completions for CVC relative to CV stems is that subjects would be expected to find and thus produce fewer words after CVC than CV stems. This lexical limitation can explain why control subjects produced words that happened to correspond to the target words (i.e. the words that were selected for study) more often after CVC than CV stems. This explanation does not, however, fully account for the production of non-presented words. On the latter, a limitation in word candidates after CVC should result directly in a depressed performance after CVC stems compared to CV stems. Such a pattern was apparent in the productions of the control subjects but not in the productions of the experimental subjects (see Table 1). Thus, on the basis of the present results, it is unclear whether the stem size effect observed in primed completion reflects an inherent limitation in word candidates or reveals the use of a phonemically based procedure. We will return to this issue in the General Discussion, after the results of the following experiments have been discussed.

## EXPERIMENT 2

In Experiment 2, explicit memory for the same material as that used in Experiment 1 was measured. Explicit memory may have contributed to performance in Experiment 1, since only 20 words could be used as stimuli for study. Subjects may have stored most of these words in episodic memory and then intentionally have drawn upon these records to augment their responses to the stems. A contribution of explicit memory to stem completion is not expected, however, to be responsible for the observed syllabic effects. Explicit memory requires little of the perceptual/lexical processing that syllabic organisation is assumed to reflect, but is rather conceived as drawing primarily on post-lexical, conceptual processing (such as meaningful processing, involving imagery and categorisation). The predominant use of conceptual information in explicit recall has been amply substantiated in the literature. We will refer to this explicit form of memory in word stem completion as the cued-recall task. As mentioned in the Introduction, semantic processing

typically produces a large advantage over non-semantic processing in cued recall. In such tasks, subjects typically study the words either semantically (e.g. by judging the pleasantness of each word) or perceptually (e.g. by judging the number of vowels contained in the word) and recall better the studied words encoded semantically. This depth of encoding effect on cued recall is highly robust and contrasts with its lack of (or weak) influence on (implicit) word stem completion (Chiarello & Hoyer, 1992; Graf & Mandler, 1984; Graf et al., 1982; Java & Gardiner, 1991; Light & Singh, 1987; Lupker, Harbuk, & Patrick, 1991; Micco & Masson, 1991; Nelson, Schreiber, & Holley, 1992; Park & Shaw, 1992; Roediger, Weldon, Stadler, & Riegler, 1992; Schacter & Church, 1992; Squire, Shimamura, & Graf, 1987).

In line with the notion that the word-stem cued-recall task requires more conceptual than perceptual processing, explicit recall of the studied words was expected to tap minimally the perceptual representations stored in the lexicon. Consequently, evidence for the use of a syllabic procedure, conceived as characterising lexical consultation, should be scarce in the present circumstances. To assess this prediction, the word-stem completion task used in Experiment 1 was transformed into a word-cued recall task. To satisfy the retrieval intentionality criteria formulated by Schacter, Bowers and Booker (1989), the task was set up with identical stimulus and response conditions as those in Experiment 1; only the subjects' understanding of the task differed. At the time of testing, subjects were instructed to complete the stems with words from the study list, and when failing to do so, to refrain from responding. This latter part of the instructions was intended to prevent subjects from resorting to unintentional recall of the studied words.

## Methods

Forty university students who had not participated in Experiment 1 were selected following the same criteria. They were assigned randomly but in equal number to the visual and auditory modality conditions. The only difference with respect to Experiment 1 concerned the instructions delivered to the subjects after the study phase. Subjects were instructed to complete each stem with a word that was previously studied; when unable to retrieve a studied word, subjects were required to say so and to respond to the next stem.

## Results and Discussion

Subjects were quite successful in inhibiting responses when failing to retrieve a studied word. In each modality of presentation, less than 6% of

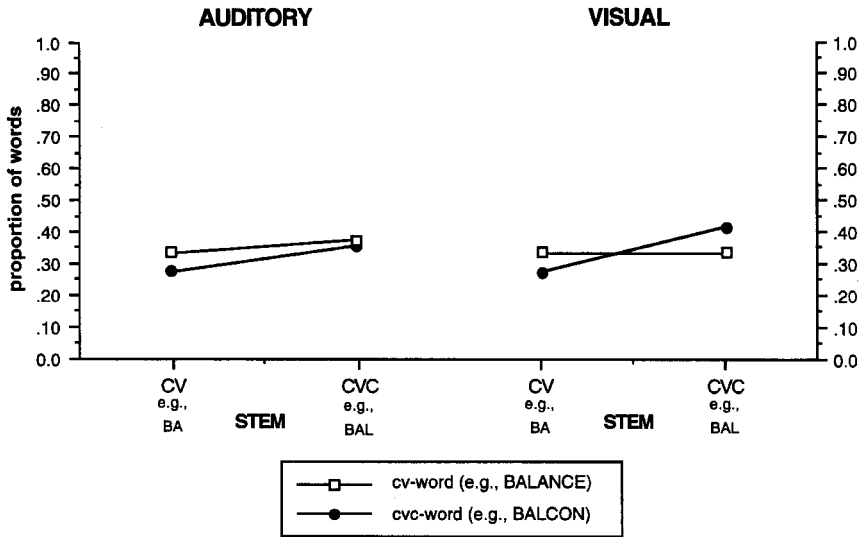
**CUED-RECALL**

FIG. 2. Mean proportion of *presented* words reported as a function of stem type and the structure of the word initial syllable in the auditory and visual modality, respectively, by French speakers in stem completion of Experiment 2. Baseline scores have been subtracted from the data.

the words produced were different from the studied words. Thus, most responses (60%) were omissions, in that subjects did not provide any response. Since word completions with studied words may nevertheless occur by chance, the baseline performance obtained in Experiment 1 was subtracted from the cued-recall scores obtained here. The resulting cued-recall performance is presented in Fig. 2 as a function of stem type and word category in each modality of presentation.

A 2 (visual *vs* auditory)  $\times$  2 (CV *vs* CVC stem)  $\times$  2 (cv-word *vs* cvc-word) analysis of variance with repeated measures on the last two factors was performed on these scores corrected for guessing. The interaction between stem type and word category was far from significant across modalities [ $F(1,38) = 1.36$ ,  $MSe = 1.78$ , NS], as well as in each modality considered separately [visual modality:  $F(1,19) = 1.44$ ,  $MSe = 1.99$ ; auditory modality:  $F < 1$ ]. Thus, as predicted in cued recall, subjects do not predominantly use the syllabic structure of the stem to retrieve words in memory. Other more conceptual characteristics of the words are probably more efficient sources of information for driving explicit recall, thereby overriding the constraints imposed by syllabic organisation.

Interestingly, modality of presentation does not appear to matter either. Unlike stem completion, cued recall performance was not found to be higher in the visual than in the auditory modality ( $F < 1$ ). This result is consistent with the notion that explicit memory is less sensitive than implicit memory to perceptual aspects of the task. The visual superiority effect found in Experiment 1 is probably related to the larger amount of perceptual processing at encoding that can take place in the visual modality. In the auditory modality, word presentation lasted about 1 sec, while in the visual modality the word remained visible on the screen for 3 sec. Since stimulus exposure time was longer in the visual modality, the perceiver may have been able to extract more perceptual information from the stimulus.

Like stem completion, however, stem size was found to have some influence on word retrieval. Subjects recalled more words when cued with a CVC than with a CV stem, at least in the visual modality [ $F(1,19) = 7.41$ ,  $MSe = 0.34$ ,  $P < 0.02$ ]. In the auditory modality, the stem size effect was not significant [ $F(1,19) = 2.78$ ,  $MSe = 0.61$ ]. This difference was supported by a stem  $\times$  modality interaction [ $F(1,38) = 8.82$ ,  $MSe = 0.48$ ,  $P < 0.01$ ]. There were no other significant effects.

The overall level of performance was found to be higher in the present cued-recall task (0.66) than in the stem completion task of Experiment 1 [0.49;  $t(78) = 4.348$ ,  $P < 0.001$ ]. This higher performance level observed when retrieval is intentional is generally consistent with the level-of-processing account of explicit memory expressions. Intentional word retrieval should act as a conceptual orienting task and therefore be associated with higher levels of memory performance than unintentional word retrieval, which would tap more automatic perceptual forms of memory. The explicit memory advantage that was observed in cued recall was not large, however. Since each stem was compatible with two studied words, of which only one had to be recalled, achieving about 66% correct was quite low. This low success rate might be related to the interference created by the presence of filler stems. In similar interfering conditions, the subjects in the studies of Marsolek et al. (1992, 1994) were also found to perform poorly (with 65% of words retrieved from explicit memory in word-stem cued recall).

In summary, all effects but the stem size effect that were indicative of perceptual processing in implicit stem completion (Experiment 1) were cancelled out by the instruction to explicitly retrieve words from memory. These perceptual effects—the syllabic effects and the visual advantage over the auditory mode of presentation—were largely absent in cued recall. Although these are null effects and thus should be treated with caution, they are highly consistent with the literature. More importantly,

the cancellation of syllabic effects when explicit or episodic memory is involved demonstrates that syllabic matching is not a general procedure for recovering words from memory, but is related to one form of memory—the one concerned with the structure of words.

### EXPERIMENT 3

The results obtained in Experiments 1 and 2 are consistent with the hypothesis that the source of the priming effects is (pre)lexical. As summarised in the Introduction, the literature on speech perception suggests that syllabic organisation of the spoken input is specific to French. This implies that English speakers should not exhibit sensitivity to syllabic structure in primed stem completion.

Partial support for this prediction can be found in a study by Cutler and her collaborators (Cutler, Norris, & Williams, 1987, experiment 3). In that study, English speakers were presented with CV and CVC targets as stems for completion with the first word that came to mind (without prior study). For both types of stems, more CVCV sequences were produced than CVCC sequences. Since these data were collected with a different purpose in mind than in the present study, an eventual match between the stem and the first syllable of the produced word was not assessed directly. However, given that, following the present criteria, CVCV sequences correspond to *cv*-words and assuming that CVCC sequences were most often *cvc*-words, then the results of Cutler et al. do not suggest a syllabic interaction. That is, CV stems did not elicit more *cv*(*cv*)-words than *cvc*(*c*)-words, or CVC stems more *cvc*(*c*)-words than *cv*(*cv*) words. Nevertheless, these subjects were not primed by prior study of a word list with unambiguous syllabic structure, as were our French speakers. Thus, the possibility still exists that the syllable structure of the stem might affect word selection in English. The aim of Experiment 3 was to assess this possibility by testing English speakers with an English version of the task used in Experiment 1.

### Methods

*Subjects.* Forty Concordia University students, all of whom had English as their native language, were tested. Eighty control college students provided the baseline data.

*Materials and Procedure.* The materials were constructed so as to mimic the French materials (see Appendix 2). Ten pairs of English words sharing the same initial CVC segment were selected. Care was taken to select initial segments that differed across the 10 word pairs and that

allowed a one-to-one mapping between the phonological and the orthographic code. The pairs were chosen so as to be comparable in terms of word frequency [from 0 to 13 per million; Francis & Kučera, 1982;  $t(18) = 0.661$ ] and word length (all words were two-syllable words). A few words (e.g. PELAGE and DOLMEN) were unfamiliar to some subjects; since both implicit memory effects and speech segmentation procedures have been shown to apply to nonwords (e.g. Cutler et al., 1987; Haist, Musen, & Squire, 1991), it was thought that inclusion of unfamiliar words would not be problematic.

In each pair, one member had a syllable boundary after the initial CVC (e.g. TEN·DON), while the other member had the syllable boundary after the initial CV (e.g. TE·NOR). Syllable boundaries were defined following the same principles as those applied to French: (a) in a  $C_1V_1C_2V_2$  sequence, the syllable boundary falls between  $V_1$  and  $C_2$ ; (b) in a  $CVC_1C_2$  string, the syllable boundary is between  $C_1$  and  $C_2$  where  $C_2$  is less sonorous than  $C_1$  according to the same sonority scale (stops, fricatives, nasals, l, r, w, y, u, i, o, e, a).

For the completion task, the initial stems of the 20 presented words (10 of CV type and 10 of CVC type) were mixed with 20 filler stems that were similar in structure but which did not appear in any of the study list items (see Appendix 2). The auditory stimuli were recorded by a male English speaker; otherwise, the procedures and equipment were identical to those used in the previous experiments.

The non-presented words provided as completion were also examined, as in the previous experiments. All words that could not be classified into the cv-word category or the cvc-word category were discarded. This was the case for words with a repeated consonant (e.g. TENNIS), words with an inter-consonantal mute vowel e in the second syllable (such as in PAVEMENT) and words beginning with unexpected syllables, such as CVCC (e.g. SALT).

## Results and Discussion

*Presented Words.* Baseline performance was analysed first to assess a putative effect of syllabic structure on word completion without prior exposure. The rates of completion with target words were 7.3 and 8.0% in the visual and auditory modality, respectively. On baseline performance, there was no indication of a syllabic effect (with a stem  $\times$  word interaction of  $F < 1$ ) but, again, as in the French experiment, subjects provided more target words after CVC stems (14%) than after CV stems (1.3%) [stem size effect:  $F(1,78) = 59.71$ ,  $MSe = 0.13$ ,  $P < 0.001$ ]. These baseline scores were subtracted from the scores of the experimental subjects.

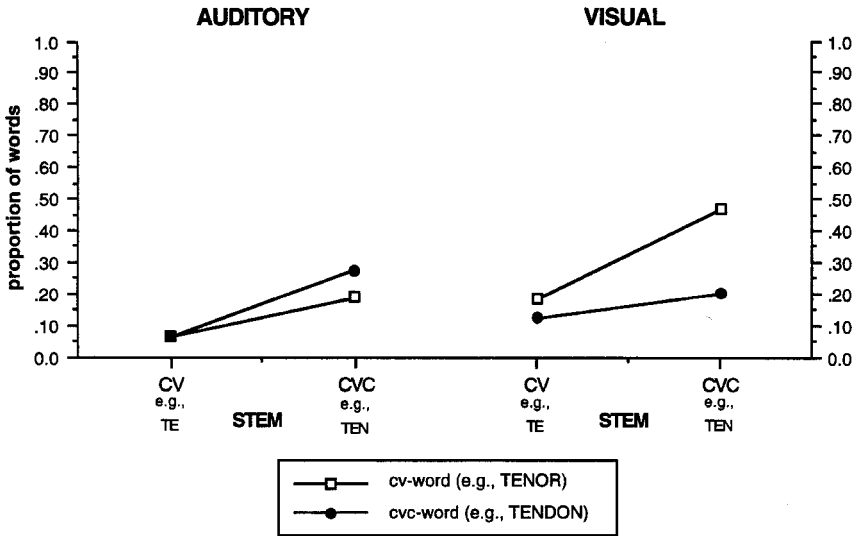
**PRESENTED WORDS**

FIG. 3. Mean proportion of *presented* words reported as a function of stem type and the structure of the word initial syllable in the auditory and visual modality, respectively, by English speakers in stem completion of Experiment 3. Baseline scores have been subtracted from the data.

As can be seen in Fig. 3, there was some indication of a syllabic effect in the auditory modality (left panel), whereas the pattern was in the opposite direction in the visual modality (right panel). The patterns observed in each modality were indeed found to be reliably different [modality  $\times$  stem  $\times$  word interaction:  $F(1,38) = 5.46$ ,  $MSe = 0.95$ ,  $P < 0.03$ ] when an overall analysis of variance was computed on these scores, with modality (auditory *vs* visual) as a between-subjects factor and stem type (CV *vs* CVC) and word category (cv-words *vs* cvc-words) as within-subjects factors. Although the patterns of responses obtained in the two modalities differed reliably, none clearly indicated the presence of a syllabic effect. As assessed by separate analyses of variance computed for each modality, the interaction indicative of a syllabic effect was far from significant in the auditory modality [ $F(1,19) = 1.50$ ,  $MSe = 0.57$ , NS]. The corresponding interaction between stem and word, which was in the opposite direction to that expected from the use of a syllabic matching procedure, fell short of significance in the visual modality [ $F(1,19) = 3.96$ ,  $MSe = 1.34$ ,  $P < 0.07$ ].

TABLE 2

Mean Proportions of Non-presented Words Provided by the Experimental and Control English-speaking Subjects as a Function of Stem Type and Word Category in Experiment 3

	<i>Stem</i>			
	<i>CV</i>		<i>CVC</i>	
	<i>cv-word</i>	<i>cvc-word</i>	<i>cv-word</i>	<i>cvc-word</i>
Experimental	0.32	0.27	0.29	0.27
Control	0.23	0.23	0.20	0.22

In addition, a significant word  $\times$  modality interaction emerged [ $F(1,38) = 11.88$ ,  $MSe = 0.89$ ,  $P < 0.01$ ] indicating that *cv*-words were more frequently produced than *cvc*-words in the visual modality [ $F(1,19) = 10.12$ ,  $MSe = 1.29$ ,  $P < 0.01$ ] but not in the auditory modality [ $F(1,19) = 1.97$ ,  $MSe = 0.48$ ]. The *cv*-word advantage is consistent with previous results reported by Cutler et al. (1987). English speakers produce more *cv*(*cv*)-words than *cvc*(*c*)-words when they are completing syllabic stems simply because the former are more frequent than the latter in the language.

As in Experiment 1 with French subjects, more studied words were produced in the visual modality than in the auditory modality [ $F(1,38) = 12.71$ ,  $MSe = 0.73$ ,  $P < 0.001$ ] and *CVC* stems elicited more studied words than did *CV* stems [ $F(1,38) = 60.65$ ,  $MSe = 0.49$ ,  $P < 0.001$ ]. Similarly, priming effects were also found to be reliable in English. The average proportion of studied words provided as completions was 0.57 in the visual modality and 0.37 in the auditory modality. Both scores differed significantly from baseline performance [ $t(58) = 14.724$  and  $9.035$ ,  $P = 0.001$ , for the visual and auditory modality, respectively].

*Non-presented Words.* As in the French experiment, all the productions that did not belong to the studied list were examined. These words were again mostly bisyllabic (57 and 50% for the experimental and control subjects, respectively), with some trisyllabic (24 and 25%) and monosyllabic words (13 and 18%); finally, very few words contained more than four syllables (7 and 8%). The stress (as specified in the Collins-Robert Dictionary, 1987) fell most often on the initial syllable of the polysyllabic words (in 66 and 55% of the words produced by the experimental and the control group, respectively). In about 17 and 13% of cases, the main stress fell on the second syllable. For the remaining words, the stress pat-

tern was more variable because they were loan words or brand names. From all these word productions, 58% of the 400 words provided by the experimental subjects and 46% of the controls' 1539 words could be classified unambiguously in a cv-word versus cvc-word category. As in Cutler et al. (1987), the productions were more often CVCV sequences than CVCC ones (with 60 vs 40% of the words so categorised). Yet, we did not obtain a significant interaction between sequence type and syllabic structure of the stem, which would have suggested the presence of a syllabic effect (see Table 2). The interaction between stem and word was clearly absent in the data of the experimental subjects ( $F < 1$ ) as well as in those of the control subjects ( $F < 1$ ).

The results obtained here indicate that, unlike francophones, English speakers are not sensitive to the syllabic value of the stem when searching through their lexicon. The lack of a syllabic influence was apparent in all forms of word completion, whether primed by the study list or not. In only one condition did English speakers produce words that appeared to follow the syllabic pattern. This condition corresponded to the auditory primed completions. Yet, the data were statistically unreliable.

In addition to a lack of evidence for a syllabic effect in English, English speakers' productions were quite similar to those observed in Experiment 1 with francophones. Subjects exhibited a stem size effect, producing more target words after CVC than CV stems, both with and without prior exposure to those words. Again, this stem size effect was not apparent when subjects were producing non-target words.

A major conclusion to be drawn from this experiment is that presenting stems in a CV or CVC format does not induce subjects to use these cues as units of segmentation, while these units might have been ignored otherwise. The syllabic effect observed in Experiment 1 appears genuine and specific to the French language.

## EXPERIMENT 4

The absence of syllabic effects in English is generally attributed to ambisyllabicity (Cutler et al., 1986); that is, boundaries between syllables are frequently unclear in English, particularly in cv-words such as SY·NONYM. According to some linguistic theories (e.g. Kahn, 1976), the first N in 'SYNONYM (where the accent is notated by an accent at the left of the stressed segment) actually belongs to both syllables. Stress may contribute to ambiguity, because a stressed syllable tends to attract the subsequent consonant into its rime. That is, a stressed CV tends towards a CVC segment, thus towards 'SYN·ONYM. Ambiguity with regard to

syllabification should, however, be greatly reduced in words with initial unstressed syllables, such as in SY'NOPSIS. In such cases, the initial CV is more likely to be perceived as an unambiguous CV syllable by English speakers.

There is good reason to consider the possibility that the pattern of stress influences the ease with which syllabic effects may be obtained. In Catalan, a language which has stress and vowel reduction like English, no syllable effect was found in a segment detection task for words with an initial stressed syllable, whereas a syllabic effect was found for words with second syllable stress (Sebastián-Gallés, Dupoux, Segui, & Mehler, 1992). Accordingly, in the present task, if all studied words contain a stress on a syllable other than the initial one, then they may give rise to syllabic effects. The evidence would be that CV stems (e.g. CO) elicit more cv-words, like CO'MEDIAN, than cvc-words, like COM'PANION, and vice versa for the CVC stems. In contrast, completion with non-studied words would reflect the general pattern, by eliciting mostly words that are stressed on the first syllable, hence functioning ambiguously with respect to the syllabic boundary. This particular set of predictions was tested here.

## Method

All 40 experimental subjects were native speakers of English from McGill University. Eighty control college students provided the baseline data. The experimental subjects were assigned randomly but in equal number to the visual and auditory mode of presentation of the materials. The materials were constructed based on the same criteria as in the preceding experiments, with the exception that all words began with an unstressed initial syllable (see Appendix 3). Finding matched pairs in terms of the initial CVC was, however, laborious. Thus, words varied in terms of the number of syllables; they consisted of two or three syllables, but syllable length was equalised in the cv-word and cvc-word categories. Except for the word selection, the procedure was identical to that used in Experiment 3.

## Results and Discussion

*Presented Words.* Baseline performance was very low, with 4% of the target words produced without prior exposure in each modality. Prior exposure raised performance to 0.54 and 0.35 studied words in the visual and auditory modality, respectively. These effects of prior exposure were again found to be reliable [ $t(58) = 14.724$  and  $12.564$ , both  $P < 0.001$ , in the visual and auditory modality, respectively].

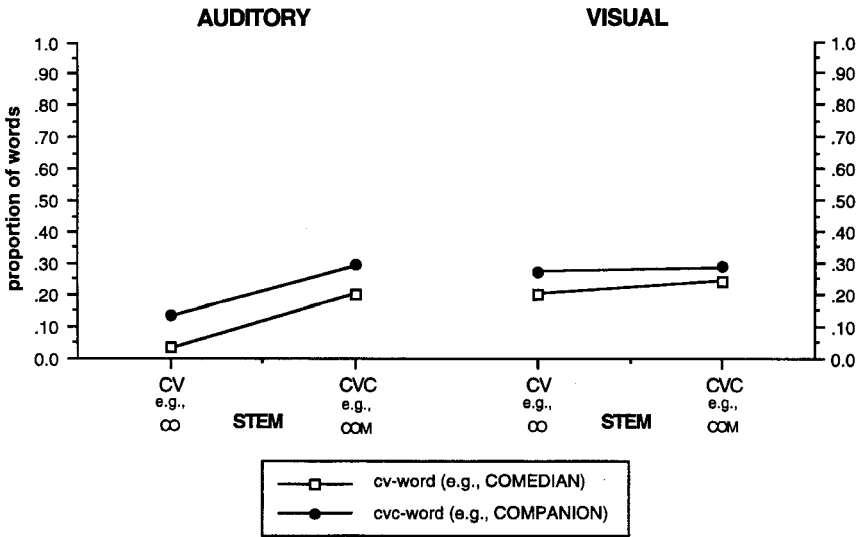
**PRESENTED WORDS**

FIG. 4. Mean proportion of *presented* words reported as a function of stem type and the structure of the word initial syllable in the auditory and visual modality, respectively, by English speakers in stem completion of Experiment 4. Baseline scores have been subtracted from the data.

To assess the effect of the stem and word structure on priming, baseline performance was subtracted from these scores. As can be seen in Fig. 4, there is no indication of a syllabic effect; the word  $\times$  stem interaction yielded  $F < 1$ , and there was no interaction between stem, word and modality ( $F < 1$ ). In general, CVC stems elicited more studied words than CV stems in the auditory modality, but this effect was not as clear in the visual modality. The interaction between stem and modality was significant [ $F(1,38) = 9.90$ ,  $MSe = 0.46$ ,  $P < 0.01$ ]. Again, more studied words were provided in the visual modality than in the auditory modality [ $F(1,38) = 12.83$ ,  $MSe = 0.69$ ,  $P < 0.01$ ]. There was also an effect of word, revealing that subjects produced more cvc-words than cv-words across modalities [ $F(1,38) = 6.15$ ,  $MSe = 0.96$ ,  $P < 0.02$ ]. This is the reverse situation to what had been observed in Experiment 3 and in the study of Cutler et al. There is as yet no obvious explanation for this reversal, except to note that it may be related to the use of words with an initial unstressed syllable.

*Non-presented Words.* The non-presented words provided by the experimental subjects as completion of the filler stems and by the control

subjects as completion with non-target words were examined following the same procedure as in the previous experiments. This led to the rejection of 47% of the 400 experimental subjects' words and 45% of the 1600 control words. The remaining word completions were mostly bisyllabic (45% in each group). More importantly, as in Experiment 3, the main stress fell on the initial syllable (i.e. in 69 and 64% of the words produced by the experimental and the control group, respectively). Only 14 and 21% of the experimental and control data, respectively, contained a main stress on the second syllable. Similar distributions were observed from auditory and visual input.

When the data were analysed as a function of the nature of the initial syllable of the produced word and the type of stem presented, essentially the same patterns as those observed in Experiment 3 emerged. No interaction between stem and word was observed in either group [ $F < 1$  and  $F(1,78) = 2.96$ ,  $MSe = 3.19$ , for the experimental and control group, respectively]

The present results show that even when the word initial syllable is unstressed, English subjects do not respect the syllabic structure of the stem in their word completion. Thus, syllables do not appear to be more significant in the later stages of word processing, such as those tapped by stem completion tasks, than in the initial stages of speech perception presumed to be tapped by monitoring tasks (Cutler et al., 1986). These results, combined with those observed in speech perception, point towards a general neglect of syllabic segmentation by English speakers.

English speakers have been shown to rely on other segmentation routines. Cutler and Norris (1988) have proposed that, in continuous speech recognition, listeners apply a metrical segmentation strategy, defined as the initiation of lexical access at the full vowel of strong syllables. Since word initial syllables are more likely to be stressed than unstressed (Cutler, 1990), experienced listeners may expect monosyllabic stems to contain a stressed syllable when they are presented in isolation. By this view, completion performance with the studied words beginning with unstressed syllables should be lower than that obtained with studied words beginning with a stressed syllable. However, the scores obtained here with unstressed initial syllables were comparable to those observed in Experiment 3 with stressed initial syllables. Moreover, subjects did not generally provide more words with initial unstressed syllables because they were exposed to such words in a study phase. Therefore, stem completion appears to be as insensitive to the stress pattern as it is to the syllabic structure of English words.

It may be premature, however, to reject the contribution of stress pattern to stem completion. First, stress is a relative cue, in the sense that a syllable is perceived as more or less accented only by comparison with

another syllable. Accordingly, perceiving stress in an isolated monosyllabic stem is mainly the product of expectations, which may correlate or interact with the phonological structure of the presented stem. Secondly, the lack of influence of stress pattern must be qualified by its dependence on acceptance of a null hypothesis, which always requires cautious consideration. This cautious note is reinforced by the fact that Finney, Protopapas and Eimeas (1996) have recently succeeded in demonstrating the role of stress pattern in syllabification in American English using an attentional phoneme monitoring task. As posited in the present study, a robust effect of syllabic structure was observed when second-syllable stress words were used, but no such effect was obtained with first-syllable stress words.

## GENERAL DISCUSSION

The major finding in the present series of experiments is that the performance of French speakers on word stem completion reflects a syllabic search procedure, whereas that of English speakers does not. These results are highly consistent with the speech perception literature and suggest that the perceptual representation system (PRS) is the likely source for these syllabic effects (and lack thereof) in implicit memory.

Francophones were found to adopt a syllabic matching procedure when completing stems with the first word that came to mind (Experiment 1). French speakers were found to complete the presented stem such that it matched the initial syllable of the word produced. That is, CVC stems (e.g. BAL) elicited the production of cvc-words (e.g. BAL·CON) more often than cv-words (e.g. BA·LANCE), whereas CV stems (e.g. BA) yielded the opposite pattern or, at times, led to comparable rates for both types of words. Consideration of stems as word initial syllables appears characteristic of lexical search. That is, evidence for the use of the syllabic matching procedure was found in all conditions requiring stem completion with the first word that came to mind, whether primed or not by prior exposure. This pattern is robust, for it replicates the pattern in another study with different subjects and slightly different materials (Peretz et al., 1996). Moreover, the use of the syllabic matching procedure was shown to characterise lexical search, not memory search. When subjects were explicitly required to retrieve words from memory, by only completing the stems using the words previously studied, they no longer exhibited sensitivity to the syllabic organisation of the words (Experiment 2). Therefore, the syllabic matching procedure does not predominate in all forms of word retrieval; it signals lexical search whether primed or not by prior exposure. Consideration of the stem as a syllabic entry into the

lexicon appears ubiquitous for French speakers. English speakers exhibited none of these effects (Experiments 3 and 4).

In other spheres of language, such as phonology (Clements & Keyser, 1983; Hooper, 1976; Kahn, 1976; Kaye & Lowenstamm, 1981, 1984, 1985; Venneman, 1974, 1978) and speech production (for English, see Sevald, Dell, & Cole, 1995; Treiman, 1983; for Dutch, see Levelt & Wheeldon, 1994; Meyer, 1991; Wheeldon & Levelt, 1995), there is general agreement that the syllable is a universal linguistic unit. Admitting language variability in the use of speech units is a recent endeavour in the psycholinguistic literature. The evidence comes essentially from empirical studies of speech perception. In speech perception, units of segmentation have been shown to vary as a function of native language. Romance languages, such as French (Kolinsky, Morais, & Cluytens, 1995; Mehler et al., 1981; Pallier et al., 1983), Spanish (Bradley, Sanchez-Casas, & Garcia-Albea, 1993; Pallier et al., 1993), Catalan (Sebastián-Gallés et al., 1992) and Portuguese (Morais et al., 1989), show positive evidence of the role of the syllable in the perception of spoken words. Germanic languages have yielded different outcomes, with Dutch being syllabically organised (Zwitserslood, Schriefers, Lahiri, & van Donselaar, 1993) but not English (Bradley et al., 1993; Cutler et al., 1986, 1989, 1992). English speakers appear to rely on other cues for segmentation, by exploiting the stress pattern (Cutler & Norris, 1988; Norris, McQueen, & Cutler, 1995). Finally, Japanese speakers employ yet another unit of segmentation, that corresponding to a subsyllabic unit, the mora (Cutler & Otake, 1994; Otake, Hatano, Cutler, & Mehler, 1993).

Thus, the current evidence is that different perceptual routines are used for different languages, depending on their phonological structure. This conclusion is provocative, for it changes the focus from the study of the assumed universality of linguistic rules to the study of processing diversity and contrasts. The supportive evidence for language specificity has, however, been essentially limited to the results obtained from monitoring tasks. The few studies that have introduced new methods have generally found converging evidence. The determining role of the syllable has been confirmed in French with a phoneme detection task (Pallier et al., 1993) and in the detection of illusory words (Kolinsky et al., 1995). In English, and contrary to previous studies, Bruck, Treiman and Caravolas (1995) succeeded in documenting syllabic effects in the comparison of spoken nonwords. However, as the authors argue, it may be the case that the syllabic organisation of words affects later stages of processing than those tapped by the monitoring tasks, since comparison of nonwords is essentially an off-line task that places heavy demands on working memory. Thus, the current evidence suggests that only tasks that assess the on-line perceptual organisation of speech will show evidence of language-specific

routines. In this respect, the present findings are important, because they provide additional evidence for language specificity while resorting to a priming memory task.

The specific pattern of primed data observed here differs slightly from that obtained in speech perception studies. Our results show syllabic effects which are generally asymmetrical. Differences in the number of cv-words and cvc-words retrieved were most apparent after CVC stems, less so after CV stems. In the monitoring studies, differences were noted in the detection of CV versus CVC targets in both cv-words and cvc-words, but in opposite directions, resulting in a crossover pattern. Another way to state the difference is that there was a general upward trend in our data: CVC stems elicited more studied words than CV stems. This trend may have tilted a crossover interaction into the observed asymmetric pattern.

The explanation for this general upward trend is that CVC stems have more in common with the studied words (all beginning with the CVC segment) than do CV stems. This size effect, which can be expressed in various ways from graphemic similarity to phonemic identity, was indeed recurrent across experiments. Both francophones and anglophones exhibited sensitivity to this factor. This is a putatively important finding, since the stem size effect appears specific to the memory component of the task. However, another account of the stem size effect is that it reflects the distributional organisation in the lexicon with at least three times as many possible word completions for CV stems as for CVC stems. Hence, selecting a word candidate that begins with a CVC is more constraining than when it begins with a CV. However, the observation that the stem size effect was generally absent when subjects produced non-presented words, suggests that the word limitation account does not fully explain the data. The explanation of the stem size effect by the adoption of a phonemically based procedure can thus be maintained, but more evidence is required to demonstrate that this interpretation is correct.

Despite the impact that stem size had on completion performance, it did not cancel out the effects of syllabification. Moreover, the stem size effect was found to be dissociable from syllabic effects. In Experiment 2, the French speakers were sensitive to the size of the stems but not to their syllabic structure in word cued recall. In Experiments 3 and 4, English-speaking subjects were found to be generally sensitive to the size of stems and quite insensitive to their syllabic status in word stem completion. Therefore, the present results indicate that the use of a syllabic matching procedure is to some extent independent of the adoption of a phonemically based approach, although the two procedures are not mutually exclusive.

One question that arises from the presence of syllabic effects in French and their absence in English in both stem completion tasks and monitoring tasks concerns the locus of syllabic information. Applying the logic of converging operations entails that both types of task be mediated by similar processes. Accordingly, syllabification should be attributed to the mechanisms that are responsible for the initial access to information about a word stored in the lexicon. Indeed, the prevailing view for the role of syllables in speech perception is that they constitute the access code to the lexicon, by providing the minimal amount of information that can activate a cohort of word candidates (Mehler et al., 1990; Segui et al., 1990). A similar theoretical position (Cutler & Norris, 1988; Norris et al., 1995) is that these segmentation processes allow detection of relevant cues or boundaries in the speech stream where lexical access can be initiated. Following both proposals, the units of segmentation that would be used at this pre-lexical stage are language-specific.

Assuming that stems initiate a search through words beginning with a given particular syllable in the French lexicon entails the following question: "To which lexicon?" If there was a single phonological lexicon, mediating both word recognition and word production as some theorists posit (Allport, 1984; Funnell, 1983), then the question would be irrelevant. However, the current evidence favours the existence of two broad classes of lexicon, a perceptual class for recognising words and a production class for expressing them (e.g. Monsell, 1987). Moreover, syllabic information may well be stored at both levels, for the requirement of syllabifying the speech stream should have some bearing on the organisation of its articulation. As reviewed briefly above, the role of syllabic structure in word production has indeed been confirmed in a variety of empirical contexts, covering speech errors (e.g. Meyer, 1991), articulation speed (Levelt & Wheeldon, 1994; Sevald et al., 1995), word games (e.g. Treiman, 1983) and naming (Ferrand, Segui, & Grainger, 1996).

The role of output factors cannot easily be dismissed in the present studies because the word-stem completion task involved a unique response mode of overt articulation. Moreover, in both the auditory and visual modality, subjects were requested to articulate each word at study. Word pronunciation was reinstated at test when completing the presented stems orally. Thus, task demands were promoting reliance on an output speech code, which apparently contains syllabic information. Accordingly, and contrary to our initial position, the emergence of syllabic effects in word stem completion can have a response origin rather than a perceptual one.

However, several aspects of the results obtained in the present study as well as in other studies cast doubt on the decisive role of output factors

in stem completion. In the present study, French speakers did not show sensitivity to the syllabic match between stem and word when performing the word-stem cued-recall task (Experiment 2). Since word production was also required at encoding and test in the cued-recall task, then any effect of syllabic organisation due to response articulation should have emerged in cued recall as well, whereas it did not. Similarly, if output factors are the determining factor, why would English speakers fail to show syllabification effects in their responses when they often show such effects in word production? (e.g. Sevald et al., 1995). This failure to exhibit sensitivity to syllabic structure in stem completion is not an isolated finding. It has been shown twice in the present study with different word lists (Experiments 3 and 4) and was also shown by Cutler et al. (1987). Thus, the results obtained here with a stem completion task do not fit well with a response origin.

Previous studies have come to the same conclusion, in showing that articulation is not a major determinant of completion performance. In two studies by Marsolek et al. (1992, 1994), subjects were exposed visually to a series of isolated words and were then asked to orally complete three-letter stems with the first word that came to mind. On the completion test, the stems were presented through brief visual exposures in either the right or the left hemifield. Laterality effects consistent with a right hemisphere advantage were obtained, depending on the format of the word presented at study and at test. If the response component of the stem completion task was indeed the determining factor of stem completion, then the overall left-hemispheric advantage should have been observed instead (Sperry, Gazzaniga, & Bogen, 1969; Wada & Rasmussen, 1960). To the contrary, the visual code used at encoding appeared to be the determining factor.

Other relevant data regarding the putative use of a speech output code in stem completion tasks come from a study that exploited a procedure known to suppress articulation. In that study (McClelland & Pring, 1991), subjects were asked to read words overtly, silently or while engaging in irrelevant articulation during stimulus presentation. The latter procedure is assumed to prevent the subjects from using a speech code in retaining the stimuli (Baddeley, Lewis, & Vallar, 1984; Baddeley, Thomson, & Buchanan, 1975). Subjects were then presented with an auditory stem completion task. Word retrieval was best in the reading aloud condition and worst under articulatory suppression. Yet, implicit retrieval of the studied words was reliable in all conditions, including the one that prevented subjects from using an articulatory code. As the authors concluded, the current evidence suggests that stem completion is not governed by output factors but by perceptual ones. The present study fits most comfortably with this conclusion.

If the primary locus of the operations that govern stem completion have a perceptual origin rather than a production one, we are left with another duality. This is related to the fact that word stem completion was performed in the auditory as well as in the visual modality. Thus, lexical search can in principle operate on a phonological and/or an orthographic representation of the words. The prevailing view would be that the orthographic representation relates more directly to a sequence of phonemes, not of syllables, as a result of learning to read alphabetically and thus to convert graphemes into phonemes (see the collection edited by Bertelson, 1986). If correct, then the syllabic effect should have been reduced in the visual modality compared with the auditory modality. This was not the case. Another possibility is that a unique phonological code was used by all subjects whether tested in the visual or auditory modality.

We have assessed elsewhere the hypothesis that the code is primarily phonological (Peretz et al., 1996) using a paradigm that is similar to that used here. We exploited words for which orthographic and phonological rules yield a different syllabification. This is the case for words containing a schwa, or a mute e, after the initial CVC, such as in CALEPIN (an English analogue would be FAMILY pronounced FAM'LY), which are referred to as *mute-e-words*. These words have a syllabic boundary after the initial CV according to orthographic rules (CA·LEPIN) and after the initial CVC according to pronunciation rules (CAL·PIN). The word CALEPIN thus has three orthographic syllables but its pronunciation is bisyllabic. The results showed that French speakers relied on a phonological representation when completing stems with words, because they considered mute-e-words phonologically—that is, being equivalent to cv-words (e.g. CALMANT) and hence different from cv-words (e.g. CALORIE)—in both the visual and the auditory modality. These results thus provide evidence that stem completion is mediated primarily by a phonological code rather than an orthographic code. Subjects' retrieval of mute-e-words appears to be dictated by the way the words are pronounced, not how they are spelled.

One result that may appear contradictory with the claim that stem completion taps an input phonological lexicon is the systematic superiority observed in priming for the visual modality over the auditory modality (Experiments 1, 3 and 4). The reverse had been expected, since the auditory input is assumed to have more direct access to the phonological code than the visual input (see Baddeley, 1986, for a review of the relevant data). However, the visual advantage observed here may have a different origin: it may be related to the static characteristics of the visual display. The printed word remains available until response, while the auditory word is ephemeral and crucially depends on a faithful record

from the listener. One way to remedy this unbalanced situation is to repeat the information in the auditory modality. This procedure was used by Bassili et al. (1989), who presented the auditory word twice every 8 sec, while visually presented words remained on the screen for the same duration. This method was successful, since subjects obtained identical levels of performance in the two modalities. Therefore, there seems to be an inherent advantage in visual presentation that is not uniquely related to the nature of the code used to process the words.

In summary, the results obtained here are most consistent with the notion that word-stem completion reflects the operations of the input phonological lexicon. In turn, the present findings can be viewed as providing further support for the view that primed stem completion, and hence implicit memory, relies on word-form representations (the PRS system; Schacter, 1992; Tulving & Schacter, 1990). In stem completion experiments, listeners have been shown here to use knowledge of the phonological structure of the words of their language. Since this knowledge differs in French and English, it provides a new dissociation that allows us to uncover the nature of implicit memory effects. Such reasoning has already been fruitfully pursued in the implicit memory domain by Watkins and Peynircioglu (1983), but at a different level of organisation of speech. In their study, English-Spanish bilinguals performed a fragment completion task after prior study of words in both languages. Subjects were found to exhibit very little cross-language priming, whereas they displayed robust same-language priming effects. Thus, these results, obtained in cross-language testing, combined with the present findings, obtained with languages having contrasting phonological structures, strongly argue for the notion that language-specific lexical processes mediate priming in stem completion tasks.

In conclusion, the present study has demonstrated that stems initiate a lexically based search through words sharing the same initial syllable in completion. This procedure is specific to French speakers, and not pertinent to English speakers, in a manner analogous to previous work carried out on spoken word segmentation. In our view, these findings should inform theories of speech perception, by expanding this domain to processes by which words are retrieved from implicit memory. Similarly, borrowing concepts and tools from the speech domain allow us to characterise better the nature of the processes involved in stem completion tasks, which have become a major tool for studying implicit memory. We thus see this study as allowing fruitful interactions between otherwise independent fields of research.

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## APPENDICES

*Appendix 1: Materials used in Experiments 1 and 2*

<i>Presented Words</i>		<i>Presented Stems</i>			
		<i>Experimental</i>		<i>Distractor</i>	
<i>cv-word</i>	<i>cvc-word</i>	<i>CV</i>	<i>CVC</i>	<i>CV</i>	<i>CVC</i>
BALANCE	BALCON	BA	BAL	BOU	BOUR
CAROTTE	CARNET	CA	CAR	CI	CIR
CHARADE	CHARDON	CHA	CHAR	DU	DUR
COUREUR	COURTIER	COU	COUR	FE	FER
FILET	FILMER	FI	FIL	GA	GAR
MURAL	MURMURE	MU	MUR	FOU	FOUR
MARAIS	MARMITE	MA	MAR	PE	PER
PALACE	PALMIER	PA	PAL	SU	SUR
TARIR	TARTINE	TA	TAR	TE	TER
VIRUS	VIRGULE	VI	VIR	VE	VER

*Appendix 2: Materials used in Experiment 3*

<i>Presented Words</i>		<i>Presented Stems</i>			
		<i>Experimental</i>		<i>Distractor</i>	
<i>cv-word</i>	<i>cvc-word</i>	<i>CV</i>	<i>CVC</i>	<i>CV</i>	<i>CVC</i>
DOLOR	DOLMEN	DO	DOL	CA	CAL
FORAGE	FORKY	FO	FOR	DI	DIS
GORY	GORGEOUS	GO	GOR	FI	FIL
MEMO	MEMBRANE	ME	MEM	GA	GAL
PALATE	PALPATE	PA	PAL	MA	MAL
PELAGE	PELVIS	PE	PEL	PA	PAN
SALAD	SALVAGE	SA	SAL	PO	POP
TALON	TALCUM	TA	TAL	SE	SEC
TENOR	TENDON	TE	TEN	SO	SOL
TONIC	TONSIL	TO	TON	VO	VOL

*Appendix 3: Materials used in Experiment 4*

<i>Presented Words</i>		<i>Presented Stems</i>			
		<i>Experimental</i>		<i>Filler</i>	
<i>cv-word</i>	<i>cvc-word</i>	<i>CV</i>	<i>CVC</i>	<i>CV</i>	<i>CVC</i>
COMEDIAN	COMPANION	CO	COM	CA	CAL
HYPOCRISY	HYPNOTIC	HY	HYP	DI	DIS
LAMENTATION	LAMPOON	LA	LAM	DO	DOL
MAGAZINE	MAGNIFICENT	MA	MAG	FI	FIL
MONOXIDE	MONSOON	MO	MON	FO	FOR
PALISADE	PALPITATION	PA	PAL	GA	GAL
RESEARCH	RESPECT	RE	RES	GO	GOR
SUBURBAN	SUBSIST	SU	SUB	ME	MEM
SYNONYMOUS	SYNTHETIC	SY	SYN	SA	SAL
VOLUNTEER	VOLCANO	VO	VOL	SE	SEC