Boundaries versus Onsets in Syllabic Segmentation

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Abstract

This study investigated the explicit syllabification of CVCV words in French. In a first syllable–reversal experiment, most responses corresponded to the expected canonical CV.CV segmentation, but a small proportion included the intervocalic consonant in both the first and second syllables, a result previously interpreted for English as indicating ambisyllabicity. Two further partial-repetition experiments showed that listeners systematically include the consonant in the onset of the second syllable, but also often include it in the offset of the first syllable. In addition, the assignment of the intervocalic consonant to the first and second syllables was differentially sensitive to the sonority of the consonant and to its spelling. We argue that the findings are inconsistent with the traditionally held boundary conception and instead support the view that distinct processes are involved in locating the onsets and the offsets of syllables. Onset determination is both more reliable and more dominant. Finally, we propose that syllable onsets serve as alignment points for the lexical search process in continuous spoken [...]
Boundaries versus Onsets in Syllabic Segmentation

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This study investigated the explicit syllabification of CVCV words in French. In a first syllable–reversal experiment, most responses corresponded to the expected canonical CV.CV segmentation, but a small proportion included the intervocalic consonant in both the first and second syllables, a result previously interpreted for English as indicating ambisyllabicity. Two further partial-repetition experiments showed that listeners systematically include the consonant in the onset of the second syllable, but also often include it in the offset of the first syllable. In addition, the assignment of the intervocalic consonant to the first and second syllables was differentially sensitive to the sonority of the consonant and to its spelling. We argue that the findings are inconsistent with the traditionally held boundary conception and instead support the view that distinct processes are involved in locating the onsets and the offsets of syllables. Onset determination is both more reliable and more dominant. Finally, we propose that syllable onsets serve as alignment points for the lexical search process in continuous spoken word recognition. © 2001 Academic Press

Key Words: syllable; syllabification; continuous speech recognition; spoken word recognition; speech perception; lexical segmentation.

Researchers have long considered the syllable to be an important structural unit in language perception and production. The syllable has been invoked as a key to the invariance problem in phonetic perception because it is considered the natural domain of coarticulation phenomena (Cole & Scott, 1974; Liberman & Studdert-Kennedy, 1978; Massaro, 1974), it plays a role in some leading models of speech production (Levitt, Roelofs, & Meyer, 1998; Levitt & Wheeldon, 1994), it has been argued to constitute a primitive in the evolution of language (MacNeilage, 1998), it has been shown to be more easily available to conscious metalinguistic manipulation than other linguistic units such as phonemes (e.g., Alegria, Pignot, & Morais, 1982; Liberman, Shankweiler, Fisher, & Carter, 1974; Morais, Bertelson, Cary, & Alegria, 1986; Morais, Cary, Alegria, & Bertelson, 1979), and it has been proposed as a potential processing unit in visual word recognition (Carreras, Alvarez, & De Vega, 1993; Prinzmetal, Treiman, & Rho, 1986; Spoehr & Smith, 1973; Taft, 1979).

Somewhat paradoxically, despite the large amount of research that the syllable has gener-
ated and its ubiquitous role in psycholinguistic theorizing, there is no consensus about the principles or rules that describe how a phonetic string is segmented into syllables. Although listeners generally agree on the number of syllables in an utterance, their syllabification choices do not always concord. The research reported here starts from this observation. Our aim is to investigate French syllabification by examining speakers’ explicit segmentation preferences in metalinguistic manipulation games. Typically in such experiments, participants hear an input sequence, which they transform according to specific instructions. For instance, in one common experimental technique (Treiman & Danis, 1988a), participants are required to repeat the syllables making up bisyllabic words in reverse order.

The paradox outlined above is also found in the linguistic literature. The syllable has become increasingly important in phonology since the early 1970s (e.g., Hooper, 1972), and most phonological theories now recognize the syllable as a fundamental unit. Several arguments justify the use of the syllable as a primitive in phonological descriptions (Hooper, 1972; Selkirk, 1982). Syllables constitute the natural domain of many phonological processes, so that phonological regularities or alternations receive simpler and more economical descriptions when the syllable environment is specified. The proposal that syllables have internal structure, characterized in terms of hierarchical constituents, provides an elegant and parsimonious account of a number of language-universal facts about phonotactics. Finally, many scholars have argued that syllables are indispensable for the description of suprasegmental phenomena such as stress and tone (see Blevins, 1995).

Despite the central status of the syllable in contemporary phonology, few, if any, languages have received an accepted and complete account of syllabification. In a review of the syllabification of French, Laeufer (1985) contrasted two general approaches to syllabification, based either on language-specific distributional constraints or on universal and abstract phonetic properties of segments. She illustrated these approaches by comparing five existing proposals and showed that they disagree on the syllabification of a large proportion of biconsonantal clusters. Similarly, in a discussion of French syllabification, Laks (1995, p. 54) reiterated the common claim that only syllable quantity is unambiguous: “In French, as in most languages, the location and the perception of the syllabic nuclei is unproblematic, while precise location of the syllable boundaries is not.” Analogous issues have been raised for English. For instance, Treiman and Danis (1988a) introduced their research as follows: “with a word like «demon», for instance, is the /m/ part of the first syllable, part of the second syllable, or part of both? Different theories of syllabification offer different answers” (p. 87).

One complicating factor is that some phonological descriptions assume that an intervocalic consonant may belong to the preceding syllable as well as to the following syllable, as illustrated in the latter citation. This double affiliation is referred to as ambisyllabicity. Kahn (1980) popularized this notion to account for diverse phonological phenomena in the pronunciation of English and specified the conditions under which an intervocalic consonant should be considered ambisyllabic. Thus, in these analyses, some segments are not uniquely assigned to one syllable.

The linguistic notion of ambisyllabicity raises some important issues about the psycholinguistic process of syllabic segmentation. Psycholinguists have generally taken ambisyllabicity in English to imply that syllable boundaries are ambiguous and hence hard to locate. However, this interpretation presupposes that listeners syllabify speech by locating the boundary between two syllables. Since ambisyllabicity implies that the offset of the first syllable does not coincide with the onset of the second syllable, as indicated by common notations such as CV[C]V, it appears logically incompatible with this conception. This incompatibility was pointed out by Selkirk (1982, p. 355), who noted: “Clearly, ambisyllabicity, if it exists, would provide a further argument against the boundary approach to the syllable: a syllable boundary cannot be simultaneously before and after some segment of the string” (see de Cornulier, 1978, for similar remarks).
In this article, we propose an alternative to the boundary approach in which the requirement that the offset of one unit corresponds to the onset of the next is abandoned. Specifically, we present a view of syllable segmentation in which locating syllable offsets and onsets constitute separate operations. We first argue that, in general, determining beginnings and endings of constituents in any input that unfolds in time may rely on different sensory cues and mental processes. Then, we suggest that the existing syllabification studies provide preliminary evidence in support of such a view.

With speech, as with other types of sequential sensory input, one function of segmentation is to assign successive packets of proximal sensory information to the distal events to which they belong. This general function can be decomposed into two operations—determining the end of one event and determining the beginning of the following. In the boundary view, these two operations are conflated. This may well be appropriate for many perceptual inputs, when the distal events are strictly sequential. Indeed, if the two events are in strict succession and the corresponding information does not overlap in time, any cue indicating the ending of the first can also be taken as informative about the beginning of the second.

However, the coupling of onset and offset decisions is not a logical necessity. In fact, there are cases in which a decision can be made about the beginning of a new event without necessarily making a commitment about the ending of the previous event. In the case of parallel or overlapping transmission of information, the cues that indicate the beginning of the new event do not correspond to the cues indicating the end of the previous one. An example can be found in syntactic parsing, in which the creation of a new subconstituent (e.g., a prepositional phrase or a center-embedded relative clause) does not require closure of the dominating constituent.

Regarding syllabification, we thus propose that locating onsets and locating offsets constitute distinct operations, and we expect that the results of the two operations do not always coincide. We further assume that when there is a conflict between onset and offset preferences, the onset decision dominates because it constitutes a primary and more fundamental process. We henceforth call this view the onset hypothesis.

The primacy of onsets is motivated by general functional considerations related to the sequential nature of the speech signal. By definition, onsets signal the beginning of a new event, which may require the immediate allocation of attentional or memory resources (Mattys, 1997). In contrast, decisions about the offset of an event do not have the same urgency and may even benefit from being delayed to resolve local ambiguity in the input. Our argument about onset primacy is in line with influential proposals in the spoken word recognition literature. Most current models attribute a special status to word onsets (Frauenfelder & Peeters, 1990; Marslen-Wilson, 1987; McClelland & Elman, 1986). Moreover, the Metrical Segmentation Strategy (Cutler & Norris, 1988) assumes that the listener uses strong syllable onsets to initiate lexical searches. In both instances, the need to process sensory information as it arrives gives onsets a privileged status.

The theoretical assumptions outlined above have direct implications for the interpretation of metalinguistic syllabification tasks, which we classify into three types. For some tasks, only onset or offset determination is relevant. One instance is the part-reduplication task used by Fallow (1981), in which participants are instructed to reduplicate either the first or the second part of the words. Presumably, only offset determination is relevant to deciding where the first part ends, and only onset determination is relevant to decide where the second part of the word starts. Thus in the present framework, part-reduplication appears to provide a relatively direct index of the result of each operation, and it should maximize the putative differences between onset and offset decisions.

Tasks of the second type require participants to combine the results of the two operations. Perhaps the clearest instance is the pause-insertion task (Gillis & De Schutter, 1996), in which participants have to repeat the spoken input and insert a pause at the syllable boundary. The location of the pause depends on both the offset
of the first part and of the second part.

The third type of task, illustrated by the syllable-reversal paradigm, requires participants to produce both parts of a word in temporal proximity. The task does not strictly require that participants determine a unique boundary, since the offset of the first response part can in principle differ from the onset of the second part. However, we assume that participants tend to obey an implicit *response-dependency constraint* consisting in avoiding the repetition of a phonemic segment. This constraint may mask potential dissociations between onset and offset determination. Given our assumption that onset decisions dominate, the response-dependency constraint should lead offset decisions to conform more often to onset decisions.

Some evidence from metalinguistic segmentation experiments may be interpreted as supporting the uncoupling of onset and offset decisions. In the experiments most directly relevant to our research, Treiman and Danis (1988a) used the syllable inversion task with bisyllabic words varying along several dimensions: stress pattern (either initial or final stress), intervocalic consonant class (liquids, nasals, or obstruents, i.e., plosives and fricatives), and orthography (single or double consonants). They observed that American listeners did not syllabify these words consistently. The intervocalic consonant was sometimes placed in the first syllable (MELON, /mE1on/→/lE1on.mE1/) and sometimes in the second (/mE1on/→/lE1on.mE1/). In addition, they observed responses which they called “1-2,” where the consonant was placed in both syllables (/mE1on/→/lE1on.mE1/). These “ambisyllabic” responses\(^1\) were more frequent with liquid and nasal consonants than obstruents, following the sonority hierarchy. An additional factor affecting participants’ responses was the spelling of the intervocalic consonant. Participants were much more likely to give ambisyllabic responses when the consonant was spelled with two letters than when it was spelled with a single letter (e.g., COMMA vs LEMON). In line with our view, ambisyllabic responses also occurred, to some extent, for words that from a linguistic point of view are not considered to include a phonologically ambisyllabic consonant (i.e., words with stress on the second syllable). Similar observations have been described for English with other metalinguistic tasks (Derving, 1992; Fallows, 1981).

The observation of ambisyllabic responses is not restricted to English. Schiller, Meyer, and Levelt (1997) tested Dutch participants with the syllable reversal task. For items with a short vowel in the first syllable (e.g., LETTER, /lE1tE1r/ and LICHAAAM, /lIxa:m/), which are considered ambisyllabic in phonological analyses of Dutch, participants generally assigned the intervocalic consonant to both syllables (/lE1tE1r/ and /xam.lIx/). Gillis and De Schutter (1996), using a variant of the pause-insertion technique, tested preliterate and literate Flemish children and also observed about 30% ambisyllabic syllabification for words in which the first syllable was stressed and contained a short vowel. A small percentage of ambisyllabic responses was also obtained for words with long vowels in the first syllable and second-syllable stress, for which no phonological ambisyllabicity is posited.

Unlike for Germanic languages, ambisyllabicity does not play a major role in phonological descriptions of French. It is only invoked in very specific contexts and it is not clear whether it means double affiliation or ambiguous affiliation. Thus, according to Laks (1995, p. 54), “Ambisyllabicity, mainly in heavy internal consonantal clusters such as fricative-stop-liquid /str/ but also in fricative-nasal /sm/, comes into play.” However, some evidence of ambisyllabic responses was recently obtained with singleton intervocalic consonants. Beaudoin (1998) used a task in which participants matched French CVCV words to three alternative orthographically represented segmentations. The main aim of the study was to compare Canadian French and English native speakers with second language learners. About 20% ambisyllabic responses were reported for monolingual French speakers tested on French stimuli.

In summary, there is already some evidence for ambisyllabic responses in several languages.

\(^1\)In line with common usage, we henceforth use the term “ambisyllabic responses” as a descriptive label for Treiman and Danis (1988a) “1-2” responses in which participants assign a given consonant to both the first and second syllable.
Overall, the proportion of ambisyllabic responses is relatively low (except when double letters are found in the orthography, e.g., Treiman & Danis, 1988a). Such responses are observed both for stimuli that phonological analyses assume to be ambisyllabic, but also, in a smaller proportion, for stimuli which do not admit an ambisyllabic analysis on linguistic grounds.

The occurrence of ambisyllabic responses provides some tentative support for our view of syllabification. Indeed, taken at face value, ambisyllabic responses reflect the fact that the onset of the second syllable does not correspond to the offset of the first. However, the observation of ambisyllabic responses is not in itself a sufficient reason to abandon the simple boundary hypothesis. For instance, one could argue that ambisyllabic responses are due to boundary ambiguity. Thus, when participants are unsure where to place the syllable boundary, they might alternate more or less randomly between two potential solutions and produce ambisyllabic responses.

Several tests may help differentiate between the two conceptions of syllabic segmentation outlined above. In the boundary view, any factor influencing offset decisions should similarly affect onset decisions, since onset and offset points represent two faces of the same coin. In contrast, the onset hypothesis allows for dissociations in the effect of different factors on onset and offset decisions. One factor that has been shown to influence syllabification is the sonority of the intervocalic consonant. The boundary view predicts that sonority should influence onset and offset decisions equally. If sonority affects the placement of a unique boundary, an increased number of first-syllable responses of the CVC type for more sonorous consonants should be mirrored by a corresponding decreasing tendency to include the consonant at the onset of the second part.

A second test builds on the analysis of task demands presented above and involves comparing performance in a syllable-reversal task to performance in partial repetition tasks. Unlike the latter, which we argued provides a direct measure of either onset or offset preferences, the reversal task requires participants to produce both parts of the stimulus in temporal proximity and is thus subject to the response-dependency constraint. Hence, in such a task, participants should syllabify more often according to the dominant onset location. Thus, the two syllabification accounts make different predictions about the effect of task requirements on syllabification. The onset hypothesis predicts little or no influence of task on the distribution of onset decisions, whereas offset decisions should vary according to the response-dependency constraint. According to the boundary hypothesis, the task manipulation should not differentially influence the pattern of syllabification responses.

In the present experiments, we examined the syllabification of French words and manipulated sonority, spelling, and task requirements in order to test these two hypotheses. To test the onset hypothesis under the most stringent conditions, we used a type of experimental stimulus—singleton intervocalic consonants in French—for which all linguistic analyses unequivocally assign the consonant to the second syllable. In our view, ambisyllabic responses reveal general, language-independent properties of syllabic segmentation processes and are not necessarily caused by specific phonological and rhythmic characteristics of languages. If onset and offset decisions indeed correspond to distinct operations, we expect to observe ambisyllabic responses even when they do not correspond to phonological ambisyllabicity. We compared performance in the syllable-reversal task, in Experiment 1, with a partial repetition task in Experiment 2. Experiment 3 used a slightly modified methodology to assess in a more direct manner the influence of response dependency.

EXPERIMENT 1

Experiment 1 tested the influence of two factors, consonant category and spelling, on onset and offset determination. To that end we examined the performance of French listeners in a syllable-reversal task using words with a single intervocalic consonant.

The experiment was designed to provide a direct comparison with Experiment 2 of Treiman
and Danis (1988a), which investigated the syllabification of analogous words in English. As mentioned above, Treiman and Danis found that both consonant sonority and spelling affected syllabification. A replication of this reversal experiment in French provides a test of the generality of the role of sonority and spelling in syllabification. However, since we wanted to assess whether consonant category and spelling differentially affected onset and offset decisions, first-syllable and second-syllable responses were scored separately for the inclusion or exclusion of the intervocalic consonant.

**Method**

**Stimuli.** The experimental items were 80 monomorphemic bisyllabic words with a single intervocalic consonant. They were divided into four groups that varied in the nature of the intervocalic consonant. The consonant could be a liquid (/l/ or /ʁ/), a fricative (/s/ or /l/), a nasal (/n/ or /m/), or a plosive (/p/, /t/, or /k/). In half of the words within each group the intervocalic consonant was spelled either by a single letter or by two nonidentical letters forming a single grapheme (e.g., BARON and SAPHIR), and in the other half it was represented by two identical letters (MARRON and SUFFIRE). The stimuli are listed in the Appendix. In addition to the test items there were 80 fillers with two intervocalic consonants (e.g., BALCON and JOURNAL). Because the syllable boundary is usually placed between the two consonants in such words, their inclusion would prevent participants from always segmenting after the first vowel.

The stimuli were randomized, divided into four blocks, and recorded by a native speaker of French onto digital audiotape, along with five monomorphemic warmup items (JARDIN, SAPIN, GALERIE, BOUTIQUE, and BOLET). Stimuli on the tapes were separated by approximately 3 s of silence.

In order to verify that the spelling manipulation was not confounded with phonetic variations, an expert phonetician measured the duration of the two vowels and intervocalic consonant in the 80 experimental stimuli. Analyses of variance were run with spelling and consonant category as factors. While there were significant differences across consonant categories on first vowel duration and consonant duration, no hint of any difference related to spelling was observed.

**Participants.** Twenty-four students at the University of Geneva participated. In this and the following experiments, all participants were native speakers of French without hearing deficits, and they received course credits for their participation.

**Procedure.** The procedure and instructions were taken from Treiman and Danis (1988a, Experiment 2). The task was presented as a language game in which participants were required to reverse the two parts of the word they had just heard. The experimenter gave some examples where the syllable boundary coincided with a morpheme boundary (“if I say CRÊVE-COEUR, you should say COEUR-CRÊVE; if I say TRICYCLE, you should say CYCLE-TRI; if I say MALSAIN, you should say SAIN-MAL”). Participants then received the five warm-up items. They were not told to respond quickly, but they were constrained to respond before the presentation of the next stimulus on the tape. At the end of the warm-up, participants were given feedback concerning their responses. For example, they were reminded that all sounds in the word had to be repeated when the word was reversed. To ensure that participants did not rely on formally learned rules of syllabification, no explicit reference to syllables was made in the instructions. Responses were recorded for later verification and also transcribed online by the experimenter. The order of presentation of the four blocks was randomized for each participant.

After the reversal task was completed, the participants were asked to write down each of the 80 test words as the experimenter read them. This was done to check that participants knew the standard spelling of the intervocalic consonant.

**Results**

The responses were analyzed in two different ways. First, we examined the responses for the first and the second syllable of the stimuli separately, each being coded in terms of whether it
included the intervocalic consonant or not. Thus, responses corresponding to the first syllable of the stimulus (henceforth called first-syllable responses) were coded as CV or CVC independently of what was produced for the other syllable (e.g., for the word PALAIS, /palɛ/, /pa/ vs /pal/, respectively). Similarly, second-syllable responses were coded as CV or V (lɛ/ vs /ɛ/). Responses in which one or more phonemes were incorrectly reproduced were coded as errors.

Second, to compare our results with previous studies, we also coded each combined response in terms of the assignment of the intervocalic consonant. Thus, as in the analyses conducted by Treiman and Danis, responses were scored as “1” if the consonant was placed in the first syllable (PALAIS, /palɛ/→/lɛ.pal/), “2” if the consonant was placed in the second syllable (/palɛ/→/lɛ.pal/), and “1-2” if it was placed in both syllables (/palɛ/→/lɛ.pal/).

In all experiments, items that yielded errors on more than 20% of the trials were removed from the analyses, as were participants for whom 10% or more of responses were errors. The word BALLET was removed as it has a homophone (BALAI) with a different spelling of the liquid. In addition, if a participant spelled the intervocalic consonant of a word incorrectly, his/her response for that item was removed from the analyses. Four items (MANÈGE, GAMMA, COMMÈRE, and RACCORD) and two participants were discarded based on the error criteria. Table 1 shows the mean proportions of responses (by subjects) according to the two coding schemes.

In the following analyses we used the proportion of CV responses for the first syllable and for the second syllable as the dependent variable. As can be seen in Table 1, CV and CVC responses for the first part and CV and V responses for the second part account for virtually all of the data, so that the complementary analyses of the proportion of CVC first-syllable responses and V second-syllable responses would be redundant. We used the CV responses because they correspond to the canonical syllabification (CV.CV). Two analyses of variance were conducted, one with subjects as the random factor ($F_1$) and one with items as the random factor ($F_2$). The means were calculated by subject and by item as described above. An arcsine transformation was then performed in order to deal with the problem of unequal variance across experimental conditions. The independent variables were the response part (first syllable or second syllable), the type of intervocalic consonant (liquid, nasal, fricative, or plosive), and the spelling of the word (one letter or two).

Overall, the responses reflect the syllabification agreed upon by phonologists. Thus, for the second syllable, 97.6% of the responses began with the intervocalic consonant. For the first syllable, 83.8% of responses were the expected CV response. The difference between first- and second-syllable responses was significant [$F_1(1, 21) = 70.84, p < .0001; F_2(1, 67) = 130.69, p < .0001$]. The effect of consonant category was significant [$F_1(3, 63) = 10.81, p < .0001; F_2(3, 67) = 4.48, p < .01$], as was the effect of spelling [$F_1(1, 21) = 9.94, p < .005; F_2(1, 67) = 6.83, p < .05$], but both were qualified by interactions with response part [$F_1(3, 63) = 25.33, p < .0001; F_2(3, 67) = 8.60, p < .0001$ for consonant category × response part, $F_1(1, 21) = 9.01, p < .01; F_2(1, 67) = 2.61, p = .11$ for spelling by response part]. No interaction was observed between consonant category and spelling (both $Fs < 1$), and the three-way interaction was significant by subjects only [$F_1(3, 63) = 3.42, p < .05; F_2(3, 67) = 1.34, ns$]. Separate analyses on first- and second-syllable responses were run to analyze the effect of consonant category and spelling in more detail.

First-syllable responses. As is shown in Table 1, fewer CV responses were observed for the more sonorous consonants [$F_1(3, 63) = 21.79, p < .0001; F_2(3, 67) = 7.88, p < .0001$]. Post hoc Tukey/Kramer HSD tests across item sets with a .05 significance level confirmed the difference between liquids and obstruents (fricatives as well as plosives). Slightly fewer CV responses were obtained for items in which the consonant was represented by two letters than for the items in which the consonant was represented by one letter [$F_1(1, 21) = 11.86, p < .005; F_2(1, 67) = 6.47, p < .02$]. No interaction
of consonant type and spelling was observed.

Second-syllable responses. There were no significant effects in this analysis. Subjects consistently assigned the intervocalic consonant to the second syllable, independently of the consonant type and of the orthographic representation of that consonant.

Additional analyses were based on the combined responses, using the proportion of ambisyllabic “1-2” responses as the dependent variable. Overall, the mean proportion of ambisyllabic responses was 13.8%. Predictably, the ANOVAs confirmed the effect of consonant type \( F_1(3, 63) = 25.47, p < .0001; F_2(3, 67) = 9.91, p < .0001 \) and spelling \( F_1(1, 21) = 10.83, p < .005; F_2(1, 67) = 5.09, p < .05 \]. Post hoc Tukey tests indicated a significantly higher proportion of ambisyllabic responses for liquids than for fricatives or plosives, with nasals intermediate. The interaction between spelling and consonant type was significant in the subject analysis only \( F_1(3, 63) = 2.86, p < .05; F_2(3, 67) = 1.02, ns \), apparently reflecting the fact that the influence of spelling was particularly marked for nasals.

Discussion

As expected, the dominant response pattern corresponded to the canonical CV.CV syllabification. However, the data were not totally homogeneous. About 14% of responses for the first syllable were of the CVC type, and these responses were always accompanied by CV responses for the second syllable. These syllabification choices substantiate the claim made in the introduction that ambisyllabic responses occur even for stimuli that do not admit an ambisyllabic analysis on phonological grounds. In line with the onset hypothesis, separate analyses of first- and second-syllable responses showed that the influence of consonant category and spelling was limited to first-syllable responses.

An additional aim of the present experiment was to compare the syllabification of singleton intervocalic consonants by French speakers with that by American English speakers. Table 2 presents the equivalent data from Treiman and Danis’s Experiment 2. In order to compare their results to ours, only the data for words with stress on the second syllable are shown, as all bisyllabic words in French have stress on the second syllable. The proportions of CV and CVC first-syllable responses and CV and V second-syllable responses were calculated from Treiman and Danis’s Table 4. For both French and English, only first-syllable responses vary substantially with sonority, and the effects of sonority are qualitatively similar. One difference between the two languages concerns the effect of spelling, which is much larger in English. Another minor difference is that the predominance of CV second-syllable responses appears slightly less marked in English than in French. Nevertheless, the overall pattern of results is strikingly similar for French and American English words with stress on the second syllable.

### Table 1

<table>
<thead>
<tr>
<th>Stimulus type</th>
<th>Example</th>
<th>First syllable</th>
<th>Second syllable</th>
<th>Combined responses</th>
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<tr>
<td></td>
<td></td>
<td>CV</td>
<td>CVC</td>
<td>CV</td>
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<tr>
<td>Liquid 1 letter</td>
<td>COLE`RE</td>
<td>73.3</td>
<td>26.2</td>
<td>98.9</td>
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<td>Liquid 2 letters</td>
<td>COLLINE</td>
<td>71.7</td>
<td>27.2</td>
<td>98.3</td>
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<tr>
<td>Nasal 1 letter</td>
<td>PONEY</td>
<td>86.8</td>
<td>9.0</td>
<td>95.2</td>
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<tr>
<td>Nasal 2 letters</td>
<td>COMMANDE</td>
<td>75.8</td>
<td>21.0</td>
<td>96.8</td>
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<tr>
<td>Fricative 1 letter</td>
<td>FACILE</td>
<td>94.8</td>
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<td>Fricative 2 letters</td>
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<td>88.6</td>
<td>8.3</td>
<td>96.9</td>
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<td>Plosive 1 letter</td>
<td>BOCAL</td>
<td>92.2</td>
<td>7.4</td>
<td>99.5</td>
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<tr>
<td>Plosive 2 letters</td>
<td>SUPPORT</td>
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<td>10.2</td>
<td>97.1</td>
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<tr>
<td>Means</td>
<td></td>
<td>83.8</td>
<td>14.1</td>
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</tbody>
</table>
As stated in the introduction, the proportion of ambisyllabic responses may be limited in tasks such as pause insertion and reversal because of the response-dependency constraint. According to this view, the proportion of ambisyllabic responses should increase for syllabification tasks in which this constraint is weakened. An alternative hypothesis is that the small proportion of ambisyllabic responses does not reflect listeners’ syllabification preferences, but rather that it is caused by the complexity of the reversal task. Intuitively, syllable reversal seems to require two operations: the segmentation of the word into two components and the manipulation of the order of the components. This intuition is supported by the occurrence of a few errors which seem to be due to the manipulation component rather than the segmentation component (e.g., *BOLIDE* → */bolid/* → */libɔd/*). Developmental evidence indicates that reversal tasks may indeed be harder than other types of metalinguistic tasks (Yopp, 1988). According to this interpretation, ambisyllabic responses should disappear if the task is made less demanding. Thus, in Experiment 2, we used a variant of the partial repetition task which weakened response dependency but could still be compared directly to Experiment 1.

**EXPERIMENT 2**

Experiment 2 used the same stimuli as in Experiment 1, but participants were tested on two separate occasions 1 week apart. They were required to produce either the first or the second part of each stimulus word. This task thus provided an opportunity to replicate the main findings of Experiment 1, using a different syllabification paradigm.

In addition, Experiment 2 allowed us to assess the influence of response dependency on syllabification responses. If the occurrence of CVC first-syllable responses in Experiment 1 is due to the complexity of the reversal task, then such responses should disappear in this experiment. Conversely, if these responses are limited by response dependency, an increase in CVC first-syllable responses should be observed.

**Method**

**Stimuli.** The stimuli and tapes were the same as those used in Experiment 1.

**Participants.** Twenty-eight students at the University of Geneva participated.

**Procedure.** Participants took part in two sessions separated by approximately 1 week. They were required to repeat one part of the word in a first session and the other part of the word in the other session. As in Experiment 1, the task was presented as a language game and explained through the use of examples and practice items, without referring explicitly to the notion of syllable. All participants received both conditions for all items. Half the participants performed the first-part repetition condition in the first session and the others performed the second-part repetition condition in the first session. The order of presentation of the four experimental blocks was varied across participants.

Following the second session, the experimenter dictated the words in order to record,
as for Experiment 1, whether the participants knew the standard spelling of the intervocalic consonant.

**Results**

The same coding system was used as for the first experiment. Two participants for whom 10% of responses or more were errors were removed from the analysis. There were no items for which more than 20% of responses were errors. As in Experiment 1, analyses of variance were conducted on the arcsine-transformed proportions of CV responses. The independent variables were the response part (first or second syllable), the type of intervocalic consonant (liquid, nasal, fricative, or plosive), and the spelling of the word (single or double letter). Mean proportions of each type of response are shown in Table 3.

Overall, the statistical analyses closely matched those of Experiment 1. There were more CV responses for the second syllable (93.3%) than for the first [54.0%; $F_1(1, 25) = 72.85, p < .0001$; $F_2(1, 71) = 440.49, p < .0001$]. The effect of consonant category was significant [$F_1(3, 75) = 15.92, p < .0001$; $F_2(3, 71) = 12.15, p < .0001$], as was the effect of spelling [$F_1(1, 25) = 10.06, p < .005$; $F_2(1, 71) = 3.91, p = .052$], but both were qualified by interactions with response part [$F_1(3, 75) = 9.39, p < .001$; $F_2(3, 71) = 4.61, p = .005$ for consonant category × response part, $F_1(1, 25) = 19.77, p < .0005$; $F_2(1, 71) = 12.16, p = .001$ for spelling by response part]. The interaction between consonant category and spelling was significant by subjects only [$F_1(3, 75) = 5.04, p < .005$; $F_2(3, 71) = 1.56, ns$], and no three-way interaction was observed (both $F$s $< 1$). Separate analyses on first- and second-syllable responses were run to analyze the effect of consonant category and spelling in more detail.

**First-syllable responses.** Fewer CV responses were observed for the more sonorous consonants [$F_1(3, 75) = 17.06, p < .0001$; $F_2(3, 71) = 13.46, p < .0001$]. Post hoc comparisons indicated that the rate of CV responses was lower for liquids than for nasals and lower for nasals than for fricatives, with plosives intermediate between nasals and fricatives.

Fewer CV responses were produced for two-letter than for one-letter items [$F_1(1, 25) = 19.36, p < .001$; $F_2(1, 71) = 13.73, p < .001$]. The interaction of consonant type and spelling was only significant in the subject analysis [$F_1(3, 75) = 3.27, p < .05$; $F_2(3, 71) = 0.8, ns$], again reflecting the trend for the spelling effect to be more marked for nasals than for any other type of consonant.

**Second-syllable responses.** As in Experiment 1, there were no significant effects in this analysis. Participants consistently assigned the intervocalic consonant to the second syllable, independently of the consonant type and of the orthographic representation of that consonant.

The influence of the task: Reversal vs repetition. One objective of this experiment was to

**TABLE 3**

<table>
<thead>
<tr>
<th></th>
<th>First syllable</th>
<th>Second Syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CV</td>
<td>CVC</td>
</tr>
<tr>
<td>Liquid 1 letter</td>
<td>45.3</td>
<td>54.7</td>
</tr>
<tr>
<td>Liquid 2 letters</td>
<td>35.6</td>
<td>64.4</td>
</tr>
<tr>
<td>Nasal 1 letter</td>
<td>61.8</td>
<td>37.8</td>
</tr>
<tr>
<td>Nasal 2 letters</td>
<td>38.3</td>
<td>61.7</td>
</tr>
<tr>
<td>Fricative 1 letter</td>
<td>71.9</td>
<td>28.1</td>
</tr>
<tr>
<td>Fricative 2 letters</td>
<td>60.2</td>
<td>39.8</td>
</tr>
<tr>
<td>Plosive 1 letter</td>
<td>63.2</td>
<td>36.8</td>
</tr>
<tr>
<td>Plosive 2 letters</td>
<td>55.9</td>
<td>44.1</td>
</tr>
<tr>
<td>Means</td>
<td>54.0</td>
<td>45.9</td>
</tr>
</tbody>
</table>
compare the syllabification patterns obtained in the repetition and reversal tasks. We conducted $2 \times 2$ analyses of variance taking the task (reversal vs repetition) as one factor and response part (first vs second syllable) as the other. The dependent variable was the arcsine-transformed proportion of CV responses. The reversal data were taken from Experiment 1 (see Fig. 1).

There was a main effect of response part [$F_1(1, 46) = 130.69, p < .0001; F_2(1, 74) = 272.23, p < .0001$]. In both tasks, the proportion of second-syllable CV responses was higher than the proportion of first-syllable CV responses. Hence in both experiments, second-syllable responses appeared more consistent with the canonical syllabic segmentation than first-syllable responses. The main effect of task [$F_1(1, 46) = 19.74, p < .0001; F_2(1, 74) = 228.07, p < .0001$] occurred because, overall, the proportion of canonical responses was higher in the reversal task of Experiment 1 than in the repetition task of Experiment 2. More importantly with regards to our predictions, the interaction was highly significant [$F_1(1, 46) = 11.72, p < .005; F_2(1, 74) = 67.67, p < .0001$]. This reflects the fact that the effect of task was largely restricted to first-syllable responses.

**Discussion**

The main finding in this experiment was the dramatic increase in the proportion of CVC first-syllable responses with respect to Experiment 1 (14.1% vs 45.9%). These responses constitute a robust phenomenon and cannot be considered an artifact of the reversal task. The increase in CVC first-syllable responses, without a corresponding change in second-syllable responses, is in line with the onset hypothesis but not with the syllable-boundary hypothesis. According to the latter view there should be perfect consistency between first-part and second-part responses, since both are determined by the same criterion—the location of the boundary between the two parts. Conversely, if onset and offset decisions are distinct, the responses for one part might be affected by different variables than the responses for the other part. Indeed, in both Experiment 1 and Experiment 2, the first syllable offset choices are variable, whereas the second-syllable onset decisions remain stable. In both experiments, only offset decisions are sensitive to sonority and spelling.

**FIG. 1.** Mean proportion of CV first-syllable responses and CV second-syllable responses in Experiment 1 (reversal task) and Experiment 2 (repetition task).
EXPERIMENT 3

Experiment 3 aimed to verify in a more direct manner that the effect of response dependency is limited to first-syllable responses. This would support the onset hypothesis by demonstrating that onset decisions are relatively unaffected by task variables and that onset decisions dominate offset decisions. We compared the independent repetition of either the first or the second part, so that no response dependency was induced, with the repetition of the two parts either in the original (forward repetition) or reversed order (backward repetition). We used a slightly different version of the reversal and repetition tasks by introducing a sentence frame ["Je dis (part 1) et puis (part 2)", “I say (part 1) and then (part 2)”] since otherwise the forward repetition condition would have amounted to plain repetition of the input.

The experiment had four conditions—repetition of the two parts in either forward or backward order, repetition of the first part only, and repetition of the second part only. Hence, the design of the experiment enabled us to compare responses for each syllable when produced alone or combined with the other. We predicted that first-syllable CVC responses should vary as a function of response dependency, whereas second-syllable responses should stay invariant. Thus, the proportion of first-syllable CVC responses should be higher for the repetition of both parts only [“Je dis (syllable 1) et puis (syllable 2)”, “I say (syllable 1) and then (syllable 2)”] than for the repetition of both parts, whatever the order. An additional aim was to test participants who spoke a different dialect of French to check that the previous findings were not specific to the dialect spoken in Geneva.

Method

Stimuli. The stimuli and tapes were the same as those used for the previous experiments.

Participants. Forty students at the University of Brussels participated in the experiment.

Procedure. Participants had to produce either one part or both parts of the stimulus words in a sentence frame. Four conditions were used: repetition of both parts [“Je dis (syllable 1) et puis (syllable 2)”], repetition of both parts in reverse order [“Je dis (syllable 2) et puis (syllable 1)”], repetition of the first part only [“Je dis (syllable 1)”], and repetition of the second part only [“Je dis (syllable 2)”]. Participants were randomly assigned to one condition. Within each condition the order of presentation of the four experimental blocks was randomized.

Participants were given written instructions presenting the task as a language game and they received the same examples and practice items as in previous experiments. Following the segmentation task, the experimenter dictated the experimental words in order to check participants’ knowledge of spelling.

Results

As in previous experiments, first-syllable and second-syllable responses were coded separately according to whether they included the intervocalic consonant. All other responses were coded as errors. There were no participants for whom more than 10% of responses were errors and no items for which more than 20% of responses were errors. As the error rate was very low (maximum of 2% in any one condition), these responses are not discussed further. As in previous experiments, syllabification responses for words whose intervocalic consonant had been incorrectly spelled were removed for each participant. In addition, three items (FISSILE, RAFFUT, and BUCCAL) were discarded because they generated a large number of spelling errors, leaving too few valid observations per group to be meaningful.

The response dependency effect. The first analysis aimed at testing the influence of response dependency. We predicted that response dependency should specifically affect first-syllable response. Hence, fewer CV first-syllable responses should be obtained in the first-syllable-only condition than in the forward-repetition condition, whereas for the second syllable the proportion of CV responses should remain high when comparing the second-syllable-only condition with the backward-repetition condition. We conducted 2 × 2 between-subjects analyses of variance with dependency as one factor (single- vs double-response conditions).
and response part (first vs second syllable) as the other. For the double-response conditions, we used the data from the forward condition for the first-syllable response and from the backward condition for the second-syllable response. Hence we compared responses for “Je dis (syllable 1)” and “Je dis (syllable 2)” either followed by the other part or not.

As shown in Fig. 2, the results conform to our prediction. There were fewer CV first-syllable responses than CV second-syllable responses \( \left[ F_1(1, 36) = 14.59, p < .0005; F_2(1, 75) = 32.73, p < .0001 \right] \), and single-response conditions tended to produce fewer CV responses than double-response conditions \( \left[ F_1(1, 36) = 2.20, p = .15; F_2(1, 75) = 39.65, p < .0001 \right] \). However, both main effects are essentially due to the lower rate of CV responses for the first syllable in the single-response condition. The interaction was significant in the item analysis \( \left[ F(1, 75) = 158.15, p < .0001 \right] \) and just missed significance in the subject analysis \( \left[ F(1, 36) = 3.93, p = .055 \right] \). Pairwise comparisons between conditions for each response part confirmed that there were significantly fewer CV first-syllable responses in the single than in the double-response conditions \( \left[ F_1(1, 36) = 6.00, p < .02; F_2(1, 75) = 21.01, p < .0001 \right] \). The slight difference in the opposite direction for second-syllable responses was significant in the item analysis only \( \left[ F_1 < 1; F_2(1, 75) = 17.15, p < .0001 \right] \).

**Effects of consonant type and spelling.** Separate analyses were run on each of the four conditions to examine the influence of consonant type and spelling. As in previous experiments, post hoc Tukey/Kramer tests were used to assess the effect of consonant type in more detail (see Tables 4–6).

In the forward repetition condition, there were main effects of consonant type \( \left[ F_1(3, 27) = 30.98, p < .0001; F_2(3, 68) = 10.64, p < .0001 \right] \) and spelling \( \left[ F_1(1, 9) = 9.38, p < .05; F_2(1, 68) = 18.00, p < .0001 \right] \) for first-syllable responses. The interaction reached significance in the subject analysis only \( \left[ F(3, 27) = 10.47, p < .0001; F_2(3, 68) = 2.46, p < .10 \right] \). Post hoc comparisons indicated a lower rate of CV responses for liquids than for any of the other three categories. For the second syllable, there was a main effect of consonant type \( \left[ F_1(3, 27) = 4.56, p < .01; F_2(3, 68) = 4.99, p < .005 \right] \). Post hoc tests indicated that the rate of

---

**FIG. 2.** Mean proportion of CV first-syllable responses and CV second-syllable responses in Experiment 3 for the single-response and double-response conditions.
CV responses was significantly lower for liquids than for nasals and fricatives.

In the backward repetition condition, for first-syllable responses, there was an effect of consonant type \[ F_1(3, 27) = 4.51, p < .05; F_2(3, 68) = 5.75, p < .005 \] and a nonsignificant trend for spelling. Post hoc comparisons indicated a lower rate of CV responses for liquids and nasals relative to fricatives. No significant effect was obtained for the second-syllable responses.

In the single-response conditions, for the first syllable, the effect of consonant type \[ F_1(3, 27) = 5.01, p < .01; F_2(3, 68) = 4.89, p < .005 \] was significant. The effect of spelling approached significance by subjects \[ F_1(1, 9) = 3.41, p < .10 \] and was significant by items \[ F_2(1, 68) = 5.62, p < .05 \]. Double-letter words led to fewer CV responses than single-letter words. According to post hoc tests, fewer CV responses were obtained for liquids than for obstruents, with nasals intermediate. Finally, for the second syllable, there was a main effect of consonant type, significant by items only \[ F_1(3, 27) = 2.49, p < .10; F_2(3, 68) = 3.50, p < .05 \] and a main effect of orthography \[ F_1(1, 9) = 6.08, p < .05; F_2(1, 68) = 3.88, p = .05 \]. Double-letter words led to more CV responses than single-letter words. However, none of the post hoc tests reached significance.

In summary, Experiment 3 confirmed that response dependency is a major determinant of first-syllable responses. Indeed, the proportion of CVC first-syllable responses was much higher in the first-syllable-only condition, in which re-

<table>
<thead>
<tr>
<th>TABLE 4</th>
<th>Mean Percentage of Responses of Various Types in Experiment 3 (Forward Repetition Condition)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First syllable</td>
</tr>
<tr>
<td></td>
<td>CV</td>
</tr>
<tr>
<td>Liquid 1 letter</td>
<td>63.5</td>
</tr>
<tr>
<td>Liquid 2 letters</td>
<td>36.9</td>
</tr>
<tr>
<td>Nasal 1 letter</td>
<td>90.8</td>
</tr>
<tr>
<td>Nasal 2 letters</td>
<td>59.6</td>
</tr>
<tr>
<td>Fricative 1 letter</td>
<td>94.8</td>
</tr>
<tr>
<td>Fricative 2 letters</td>
<td>78.8</td>
</tr>
<tr>
<td>Plosive 1 letter</td>
<td>74.8</td>
</tr>
<tr>
<td>Plosive 2 letters</td>
<td>73.9</td>
</tr>
<tr>
<td>Means</td>
<td>71.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE 5</th>
<th>Mean Percentages of Responses of Various Types in Experiment 3 (Backward Repetition Condition)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First syllable</td>
</tr>
<tr>
<td></td>
<td>CV</td>
</tr>
<tr>
<td>Liquid 1 letter</td>
<td>57.6</td>
</tr>
<tr>
<td>Liquid 2 letters</td>
<td>48.8</td>
</tr>
<tr>
<td>Nasal 1 letter</td>
<td>66.4</td>
</tr>
<tr>
<td>Nasal 2 letters</td>
<td>47.9</td>
</tr>
<tr>
<td>Fricative 1 letter</td>
<td>86.2</td>
</tr>
<tr>
<td>Fricative 2 letters</td>
<td>69.1</td>
</tr>
<tr>
<td>Plosive 1 letter</td>
<td>62.7</td>
</tr>
<tr>
<td>Plosive 2 letters</td>
<td>68.8</td>
</tr>
<tr>
<td>Means</td>
<td>63.4</td>
</tr>
</tbody>
</table>
response dependency is eliminated, than in the forward-repetition condition, and no such difference was obtained for second-syllable responses.

In contrast with previous experiments, small effects of consonant category and spelling were obtained for second-syllable responses, in the single-response condition as well as in the forward repetition condition. However these effects were much smaller than those observed for the first syllable and thus do not contradict our major claims.

**GENERAL DISCUSSION**

In the introduction we presented two opposing views of syllabic segmentation. The **boundary view** assumes that syllabification involves determining the unique juncture point between two constituents. In contrast, according to the **onset hypothesis**, determining the initial and final edges of syllables constitutes two distinct processes, and onset determination prevails over offset determination.

We proposed two tests of the onset hypothesis by examining the syllabification of singleton intervocalic consonants by French native listeners. The first examined whether onset and offset decisions were equally affected by stimulus characteristics known to influence syllabification. The boundary hypothesis predicts that any factor influencing offset determination should influence onset determination similarly, whereas the onset hypothesis allows for differential effects. The second test assessed the influence of task demands on onset and offset decisions. We predicted that second-syllable responses, which require locating syllable onsets, should not be affected by task variations. In contrast, first-syllable responses, which reflect offset decisions, may well be biased by task demands.

In the first test, we manipulated two factors, the type of intervocalic consonant and its spelling. In most experimental conditions, clear and significant effects of both factors were observed on first-syllable responses (syllable offset) only. We recently replicated this response pattern with French children, using a different stimulus set (Content, Frauenfelder, & Dumay, 1999). We adapted the part repetition task used in the present experiments to test 5- and 8-year-old children. In both age groups, only first-syllable responses were affected by consonant sonority. In addition, in the literate group, first-syllable responses varied as a function of spelling. Neither factor influenced second-syllable responses.

The second test also provided support for the onset hypothesis. We compared the response patterns obtained in the syllable reversal task (Experiment 1) with those in the repetition task (Experiment 2). A significant interaction between task and response part was observed, due to fewer first-syllable CV responses in Experiment 2. Experiment 3 provided a more straightforward test of the response dependency effect by comparing single-response and double-response conditions directly. Again, participants

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**TABLE 6**

Mean Percentage of Responses of Various Types in Experiment 3 (Single-Response Conditions)

<table>
<thead>
<tr>
<th></th>
<th>First syllable</th>
<th>Second syllable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CV</td>
<td>CVC</td>
</tr>
<tr>
<td>Liquid 1 letter</td>
<td>36.6</td>
<td>62.4</td>
</tr>
<tr>
<td>Liquid 2 letters</td>
<td>28.0</td>
<td>70.9</td>
</tr>
<tr>
<td>Nasal 1 letter</td>
<td>52.4</td>
<td>46.5</td>
</tr>
<tr>
<td>Nasal 2 letters</td>
<td>35.8</td>
<td>64.2</td>
</tr>
<tr>
<td>Fricative 1 letter</td>
<td>52.8</td>
<td>46.3</td>
</tr>
<tr>
<td>Fricative 2 letters</td>
<td>40.9</td>
<td>59.2</td>
</tr>
<tr>
<td>Plosive 1 letter</td>
<td>47.8</td>
<td>48.1</td>
</tr>
<tr>
<td>Plosive 2 letters</td>
<td>48.7</td>
<td>49.1</td>
</tr>
<tr>
<td>Means</td>
<td>42.9</td>
<td>55.8</td>
</tr>
</tbody>
</table>
were more likely to give CVC first-syllable responses when instructed to produce only the first part of the stimuli than when they had to produce both the first and the second syllables. No such variation was observed for second-syllable responses.

In sum, the results of both tests are consistent with the view that locating syllable onsets and offsets obey different constraints. The findings provide empirical support for the onset hypothesis. In what follows, we discuss the observed pattern of onset and offset segmentation choices in light of linguistic and psycholinguistic evidence. We then consider the implications of the onset hypothesis for theories of lexical segmentation and word recognition in continuous speech and for the issue of differences and similarities in lexical processing across languages.

Regarding syllable onset preferences, the systematic assignment of the intervocalic consonant to the onset of the second syllable observed in the present experiments is consistent with general principles of syllabification (e.g., Selkirk, 1982; Venneman, 1988; but see Blevins, 1995; Breen & Pensalfini, 1999, for some possible counterexamples). According to the Obligatory Onset Principle (OOP; Hooper, 1972) an intervocalic consonant is affiliated with the following vowel as long as there is no violation of phonotactic constraints. This general preference conforms to cross-linguistic regularities in the distribution of syllable types (see Blevins, 1995, for a review).

According to linguistic descriptions, the OOP may conflict with other constraints. One such constraint, known as the Weight Law (Venneman, 1988) or Stress Principle, concerns the influence of lexical stress. Syllables bearing primary stress tend to be heavy and include either long vowels or a filled coda position. Another phonotactic constraint, sometimes termed the Branching Rhyme Constraint (Schiller et al., 1997), states that open syllables with short/lax vowels are not allowed. Neither of these generalizations applies in French. Open syllable types clearly predominate (Goldman, Content, & Frauenfelder, 1996), and stress is not lexically contrastive and falls on the final syllable in list pronunciation. Given that any singleton consonant used here is a possible word onset, the OOP predicts the systematic affiliation of the consonant to the onset position, as we observed.

The frequent assignment of the intervocalic consonant to the onset of the second syllable has also been observed in most previous studies of singleton consonant syllabification, although the pattern varies somewhat across languages. In Dutch, both Gillis and De Schutter (1996), with 5- and 8-year-olds, and Schiller et al. (1997), with adults, examined the syllabification of singleton consonants in bisyllabic words and manipulated stress and vowel length. In both studies, nearly all responses conformed to the OOP in all conditions. Thus, Schiller and coworkers (1997, p. 124, author's italics) conclude that although “stressed syllables attract coda consonants ... We cannot argue that a stressed second syllable ‘takes away’ the intervocalic consonant from the first syllable because all second syllables, stressed or unstressed, were provided with an onset.” Derwing (1992) described a similar tendency for Swiss German.

In contrast, the available evidence in English suggests that stress and vowel quality affect both first-syllable and second-syllable responses. In Treiman and Danis’s (1988a) syllable reversal experiments, the consonant was less often assigned to the second syllable in first- than in second-syllable stress words (Experiment 2, 56% vs 91%) and within first-syllable stress words for short/lax than for long/tense vowels (Experiment 3, 61% vs 76%). Similarly, in Derwing’s (1992) study, in which participants were required to choose between three different syllabifications (coda of first syllable, onset of second syllable, or ambisyllabic), coda assignment was the predominant choice for words with first-syllable stress which contained a lax vowel and a liquid or nasal intervocalic consonant.

Thus it appears that in various languages, conflicts between the OOP and other syllabification constraints are generally resolved by honoring the OOP and assigning the intervocalic consonant to the second syllable. The English data seem to depart from this generalization to some degree, suggesting that other factors besides stress and vowel length might play a role. One
potential factor worth examining in further research is vowel reduction, the tendency to neutralize vowels in unstressed syllables, which is a frequent phonological process in English but not in Dutch.

Regarding syllable offset preferences, the influence of consonant sonority observed in this study is consistent both with descriptive regularities and psycholinguistic evidence. Clements (1992) argued that there is a universal preference across languages for syllables in which the sonority decreases minimally from the vowel peak to the right edge. Accordingly, sonorous consonants, such as liquids and nasals, constitute more preferred codas than less sonorous consonants such as fricatives or plosives. Despite the predominant open-syllable structure of French words, the distribution of onset and coda consonants in the lexicon seems to support the sonority sequencing generalization. We estimated the frequency of single onset and single coda consonants from the LEXOP database (Peereman & Content, 1999). As shown in Table 7, obstruents are more likely to appear at onset than at coda position, and conversely, liquids are more likely to appear at coda than at onset position. While more subtle regularities in CV and VC co-occurrence patterns do exist (see, for English, Kessler & Treiman, 1997), it appears that the sonority sequencing generalization captures one important phonotactic fact of French.

The preference for more sonorous consonants in coda position is reflected in experimental data as well as in some aspects of language use. Such a trend appeared in Treiman and Danis’s (1988a) data. As shown in our re-analysis, for second-syllable-stress words, clear effects of spelling and sonority were present for first-syllable responses. Gillis (1996) also observed large effects of sonority in both 5- and 8-year-old children. Other psycholinguistic evidence, based on speech errors in children and aphasic patients (Christman & Depaolis, 1996; Romani & Calabrese, 1998), word games (Treiman, 1983, 1984; Treiman, 1986), and phoneme recombination errors in short-term memory tasks (Treiman & Danis, 1988b; Treiman, Straub, & Lavery, 1994), also indicates that more sonorous consonants are more cohesive with the preceding vowel.

The observation that first-syllable responses are sensitive to spelling is again consistent with previous findings (Gillis & De Schutter, 1996; Schiller et al., 1997; Treiman & Danis, 1988a). However, the effect of spelling was stronger in Treiman’s experiments than in the present study. One may wonder whether these effects are due to the contamination of syllabification processes by spelling or hyphenation rules or rather to subtle differences in pronunciation reflected in the orthography. We believe that the latter possibility is unlikely. Although there is a recent trend in some dialects of French to pronounce double letters as geminates, this type of pronunciation is considered very formal, it is generally limited to some prefixed forms, and is not considered contrastive. Furthermore, in phonetic analyses of the stimuli used in the present study, we found no trace of geminate realizations of orthographically doubled consonants.

In conclusion, the main results of the present experiments are in line with previous findings in similar syllabification experiments as well as with linguistic descriptions of syllabification. Neither the predominant affiliation of the inter-vocalic consonant with the second syllable nor the trend to produce more closed-syllable responses for more sonorous consonants seems

| TABLE 7 | Relative Frequency of Major Consonantal Classes in Onset or Coda Position |
|---------------------|---------------------|---------------------|---------------------|---------------------|
| Consonant category | Type count           | Token count         | Consonant category | Type count           | Token count         |
|                    | Onset | Coda   | Onset | Coda   | Onset | Coda   |
| Obstruents         | .74   | .63    | .73   | .27    |
| Nasals             | .13   | .11    | .13   | .12    |
surprising as such. Perhaps the most interesting finding is that the latter trend is observed even when everything concurs in assigning the intervocalic consonant unequivocally to the second syllable. Our results, together with the Dutch data (Gillis & De Schutter, 1996; Schiller et al., 1997), suggest that the constraints that determine syllable offsets do not systematically influence syllable onset decisions.

The Role of the Syllable in Spoken Word Recognition

The early discussions about the function of the syllable in speech processing focused on the question of its “psychological reality as a perceptual unit” (Savin & Bever, 1970). However, it has become clear that this question is too vague and needs to be refined. In this regard, Cutler and Norris (1988, p. 114) introduced an important distinction between segmentation and classification. They stated: “The process of classification is logically distinct from the process of segmentation. Segmentation means making a division at some point in the signal. Classification means identifying units occurring in the signal. In order to classify speech into any sequence of units (phonemes, syllables, or feet) the recognizer must indeed segment the speech signal at the boundaries of these units. But the reverse is not true: It is possible to segment speech without classifying it.”

The distinction has a direct bearing on the role of the syllable and may help clarify the present discussion. Indeed, authors such as Mehler and colleagues (e.g., Mehler, Dupoux, & Segui, 1990) have argued that the syllable constitutes a primary classification unit for French speakers. Others, such as Cutler and Norris (1988), have insisted on the role of the syllable in segmentation. The present data are compatible with the latter view that syllable onsets help listeners segment the speech flow. They are harder to reconcile with theories assuming prelexical syllabic categorization.

Mehler, Dupoux, and Segui (1990) assume that the signal is recoded and categorized prelexically in terms of syllable-sized units. In their view, “speech is segmented into elementary units that roughly correspond to the syllable. [...] Syllabic frames are recognized by a bank of syllabic analyzers. [...] Phonemes do not play a direct role in speech perception but are derived from a prelexical code, namely from the syllabic frames” (p. 255). Perhaps the most influential argument in favor of prelexical syllabic classification units comes from the finding of an effect of syllable structure in the fragment detection task. In a seminal study, Mehler, Dommeregues, Frauenfelder, and Segui (1981) reported that French listeners were faster to detect targets which correspond exactly to the first syllable of a stimulus word (e.g., “ba” in balance or “bal” in balcon) than to detect targets which correspond either to more or less than the first syllable (“ba” in balcon or “bal” in balance). Follow-up experiments (Cutler, Mehler, Norris, & Segui, 1986) comparing the performance of English and French speakers tested on both French and English materials revealed a syllable effect for French speakers on English materials. In contrast, English participants showed no such effect for either the French or the English materials. This finding demonstrates that the effect can be attributed not just to differences in the respective acoustic/phonetic realizations of the words, but also to differences in the perceptual process for the two languages.

The syllable detection paradigm has since been used for various cross-linguistic comparisons (see, e.g., Kolinsky, 1998, for a review; Tabossi et al., 2000). These data have contributed to the wide acceptance of the notion that the syllable plays a central role as a classification unit in the processing of French. Nonetheless, we believe that they do not provide conclusive evidence to support such a claim. Several authors have argued that the syllable effect in fragment detection experiments may not reflect early perceptual processing (Frauenfelder & Kearns, 1996; Kolinsky, 1998) and might involve postlexical matching/decision processes (McQueen, 1998). In fact, in a reanalysis of the original data, Dupoux (1993) showed that the target/carrier interaction was only observed for slower participants. Kolinsky (1998) further noted that the detailed pattern of reaction times observed in the fragment detection experiment for French does not exactly fit
with the predictions of a syllabic classification account. In particular, she argued that a larger RT difference than that actually observed would be expected between CV and CVC targets in CV carriers (e.g., “ba” and “bal” in balance) because in the latter condition, responses should be delayed until the second syllable has been recognized.

In a set of syllable detection experiments using pseudoword target-bearing sequences with French-speaking adults, we failed to observe the syllable effect in most of the conditions tested (Content, Meunier, Kearns, & Frauenfelder, in press). Moreover, the amount of signal that participants required in a gating task to identify the first vowel and the pivotal consonant correlated extremely strongly with the detection latencies to CV and CVC targets, respectively. Such correlations indicate that the incoming sensory information is used immediately as it arrives and suggest that a subsyllabic classification unit mediates the detection process.

Other techniques have provided further evidence of listeners’ sensitivity to syllabic structure. One technique is based on the manipulation of attentional expectations. Pallier (1993) showed that phoneme detection was facilitated when participants were led to expect the target phonemes to occur in a fixed syllabic position. No such effect was obtained in control conditions in which the expectation was based on the absolute position of the target phonemes. Similar effects of attentional allocation have also been observed in English (Finney, Protopapas, & Eimas, 1996; Pitt, Smith, & Klein, 1998). Another technique relies on illusory combinations of fragments of dichotic stimuli. Using CVCV stimuli, Kolinsky, Morais, and Cluytens (1995) examined the probability of illusory percepts resulting from the recombination of various parts of the two inputs. They observed that syllable blends were more frequent than blends involving two adjacent but not tautosyllabic segments. While the findings based on both techniques clearly demonstrate that listeners are sensitive to syllabic structure in processing incoming speech, they do not decide between a syllabic segmentation and a syllabic classification hypothesis. In sum, we would argue that there is little unequivocal evidence to support the hypothesis that syllables serve as prelexical coding units in any language.

According to our view, rather than serving as classification units, syllables are involved in segmentation. More precisely, syllable onsets help the listener segment the speech flow. This onset segmentation process might serve various functions. As suggested in the introduction, onset segmentation might index the beginning of new events in the continuous speech stream and determine the allocation of resources. Given that syllable onsets and word onsets frequently coincide, a syllable onset segmentation strategy may also provide a useful heuristic for determining potential word beginnings. In this view, the detection of syllable onsets would help lexical segmentation by providing the lexical search mechanism with privileged alignment points in the signal (or its prelexical representation). According to this heuristic, any syllable onset is taken to be a possible word onset.

The findings reported here support this view by showing the robustness of onset decisions in speakers’ explicit segmentation choices. However, because they are based on offline metalinguistic tasks, it is unlikely that they tap directly into early perceptual processing. Various authors (e.g., Kolinsky, 1998) have warned against directly inferring perceptual processing from deliberate and conscious decision processes. While a detailed description of the mechanisms determining participants’ behavior in syllabification experiments is currently not available, we assume, in line with other researchers using metalinguistic tasks, that perceptual processes and representations may partially determine these explicit choices.

Other data from online word recognition tasks support the hypothesis that syllable onsets are detected during perceptual processing and help determine the initial cohort of lexical candidates. In a cross-modal semantic priming experiment, Vroomen and de Gelder (1997, Experiment 3) examined the influence of alignment between embedded words and their nonword carriers. They found significant facili-
When the prime word was embedded at the onset of the carrier (VEL, “animal skin,” in VELK, as a prime for HUID, “human skin”) but no facilitation when it was embedded at the offset (WIN, “wine,” in TWIN, as a prime for ROOD, “red”).

In a recent word spotting study, Dumay, Frauenfelder, and Content (submitted) assessed the cost of a misalignment between the onset or the offset of the target words and the syllable boundary of the target-bearing carriers. French participants had to detect words embedded in bisyllabic nonsense carriers such that the onset of the target could be aligned or not with the onset of the second syllable of the target-bearing sequence (e.g., LAC in /zyn.lak/ and /zy.glak/, respectively). In another condition, the target words were embedded in initial position to assess the effect of offset misalignment (e.g., LAC in /lak.tyf/ vs /la.klyf/). Based on the syllable onset segmentation hypothesis, we expected that onset misalignment would create more interference. In line with our prediction, the negative effect of a misalignment was greater for the onset condition than for the offset condition, the latter effect failing to reach statistical significance.

Similar findings have been reported by McQueen (1998) with Dutch listeners. In that study, participants had more trouble detecting words embedded at the end of nonsense carrier sequences when the onset of the words was not aligned with the syllable boundary (e.g., ROK in /fi.drok/ vs /fi.m.rok/). Based on the syllable onset segmentation hypothesis, we expected that onset misalignment would create more interference. In line with our prediction, the negative effect of a misalignment was greater for the onset condition than for the offset condition, the latter effect failing to reach statistical significance.

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Similarities and Differences in Processing across Languages

As Cutler and Otake (1996) have argued, “a psycholinguistic model of speech processing must attempt to account for universal characteristics of the human language production and language comprehension system, but at the same time to explain how language specific structural features affect the processing of individual languages” (p. 2). Indeed, the differences between the performance of English and French listeners in the fragment detection task led Cutler et al. (1986) to propose that listeners employ language-specific segmentation procedures based on the rhythmic properties of their native language and that a syllable-based access procedure is more appropriate for French than for English.

In contrast, the present study reveals striking similarities between the syllabification of singleton intervocalic consonants by French and English speakers, at least when words with similar stress patterns (second-syllable stress) are compared. In Treiman and Danis’s (1988a) experiments as well as in the present study, the majority of second-syllable responses include the consonant, and only first-syllable responses vary substantially with sonority and spelling. The similarity of the results across languages suggests that both languages share an analogous onset detection process.

One finding in English that appears to contradict this claim is the distribution of responses for words with first- rather than second-syllable stress. This large variability in onset decision appears at first to be problematic for our account since we claim that onset detection is primary and highly reliable. The contradiction is more apparent than real, however, if one additionally assumes that only strong-syllable onsets are salient and reliably detected. It is precisely this claim that Cutler and Norris put forward as the Metrical Segmentation Strategy (Cutler & Norris, 1988). According to this view, lexical lookup is initiated only at the onset of strong syllables, which contain full vowels. Weak syllables, which are unstressed and contain reduced vowels, do not trigger lexical searches. Most if not all of Treiman and Danis’s (1988a) first-syllable-stress words had a strong-weak metrical pattern, as typical for bisyllabic words in English. Therefore, no salient onset point would be marked for the second syllable. In French, by
contrast, there is no analogous process of vowel reduction, so even unstressed vowels are fully realized and one may assume that all syllables are strong. Hence, the restriction of the onset hypothesis to strong syllables appears to provide a parsimonious account of both the English and the French data and underscores the similarities in processing between French and English more than the differences.

Conclusions

The present study provides evidence against the commonly accepted boundary view of syllabic segmentation. By demonstrating clear disassociations between syllable onset and offset decisions, it supports the alternative hypothesis according to which listeners rely on syllable onsets for continuous speech segmentation. We believe that these findings are important because they lead to a view of speech perception in which syllable onsets provide privileged entry or reference points for segmentation and lexical access. The findings also suggest that there may be more similarities than previously thought between syllabic segmentation processes in Romance and Germanic languages. Indeed, our results point to the existence of general, perhaps even universal, speech segmentation routines.

APPENDIX

List of Stimuli Used in the Experiments

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