# Activation of segments, not syllables, during phonological encoding in speech production

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Two experiments are reported that tested whether syllables can be primed in English speech production using a (masked) priming paradigm. In Experiment 1, we presented masked syllable primes for 45 ms. In Experiment 2, primes were presented for either 45 ms or 105 ms under unmasked conditions. In both experiments, we tested three different SOAs, namely −200 ms, 0 ms, and +200 ms. Both under masked and under unmasked conditions phonological priming effects were obtained. However, no evidence for a syllabic priming effect was found. Instead, at SOAs −200 ms and 0 ms, priming effects increased when the segmental overlap between prime and target was increased. This outcome supports a segmental overlap account but contradicts the syllable priming hypothesis. The theoretical implications of the results for current theories of phonological encoding are discussed.

**Keywords:** speech production, phonological encoding, syllable priming effect, masked priming

Phonological encoding in speech production refers to the retrieval of word forms from the mental lexicon. One question to ask is: "What are the relevant phonological units speakers retrieve during phonological encoding?" Syllables may be a good candidate for playing an important role in phonological encoding. Indeed, the two most influential models of phonological encoding assume the existence of syllabic units (Dell, 1986, 1988; Levelt, 1989, 1993; Levelt,

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Roelofs, & Meyer, 1999). Despite this general agreement, these models widely differ in the status of syllabic units in phonological encoding.

In Dell's (1986, 1988) model, for instance, the phonological composition of a word is already syllabified in the lexicon. This model includes abstract structural representations: During word form retrieval, word form nodes not only activate their phonological syllabic units (chunks of segments) but also syllabic frames, so-called *word shape headers*, that specify the CV structure of the syllable (see MacNeilage, 1998, for a similar view). The word *bas.ket* (syllable boundary indicated by dot), for instance, would activate the structure CVC (C stands for consonant, V for vowel) twice, whereas the word *pi.lot* would activate a CV and a CVC word shape header, corresponding to the first and second syllable. These word shape headers or frames will later serve as placeholders into which segmental content will be inserted during the process of segment-to-frame association.

Some researchers have actually found effects of abstract syllabic structure supporting Dell's idea of word shape headers (e.g., Costa & Sebastián-Gallés, 1998; Ferrand & Segui, 1998; Meijer, 1996; Sevald, Dell, & Cole, 1995), while others did not find such effects (e.g., Roelofs & Meyer, 1998) or accounted for such effects by an articulatory explanation (e.g., Van Lieshout, Hijl, & Hulstijn, 1999). Roelofs and Meyer (1998) found effects of shared number of syllables and shared stress pattern in the presence of shared segmental information, but failed to obtain any effect of shared CV structure.

In contrast to Dell (1986, 1988), Levelt's (1989, 1993) model assumes that word forms are *not* syllabified in the lexicon; instead syllables are computed on-line during a syllabification process (for a brief description of Levelt's model see Schiller, 2000, pp. 512–513). Levelt (1993) included another level of representation where syllables play an important role. Following Crompton's (1981) suggestion, Levelt proposed the existence of a *mental syllabary* (Aichert & Ziegler, 2004; Cholin, Levelt, & Schiller, 2006; Levelt & Wheeldon, 1994; but see Wilshire & Nespoulous, 2003). The syllabary contains the articulatory specifications for, at least, the high-frequency syllables in the language (Schiller, Meyer, Baayen, & Levelt, 1996).

In spite of the experimental efforts devoted to the study of the role of the syllable in phonological encoding (e.g., Brand, Rey, & Peereman, 2003; Cholin, Schiller, & Levelt, 2004; Ferrand, Segui, & Grainger, 1996; Ferrand, Segui, & Humphreys, 1997; Fowler, Treiman, & Gross, 1993; Levelt & Wheeldon, 1994; Schiller, 1998, 1999, 2000; Schiller, Costa, & Colomé, 2002; Schiller, Meyer, & Levelt, 1997; Sevald et al., 1995; Treiman & Danis, 1988), the evidence in favor of such a unit is still scarce and sometimes contradictory. In the present study, we provide more experimental evidence regarding the syllable's role during phonological encoding.

The most compelling experimental *on-line* evidence for the existence of syllables in phonological encoding is the so-called *syllable priming effect* obtained by Ferrand et al. (1996, 1997) for French and English. In one of their experiments, participants were asked to name pictures in French, the names of which started with a CV syllable, for instance, *pa.lace* ("palace"), or with a CVC syllable, for instance, *pal.mier* ("palm"). Targets were preceded by a CV (*pa*) or a CVC (*pal*) prime presented under visually masked conditions for a short period of time (29 ms). The results of the experiment showed an interaction between the type of target (CV or CVC) and the type of prime (CV or CVC) revealing that: a) CV primes such as *pa* led to shorter naming latencies for CV targets such as *pa.lace* than CVC primes such as *pal*, and b) CVC primes such as *pal* led to shorter naming latencies for CVC targets such as *pal.mier* than CV primes such as *pa*. Similar effects were found in word and nonword naming, but not in lexical decision. Since the latter task does not require the computation of a phonological representation, Ferrand et al. (1996, 1997) concluded that the syllable priming effect arises at the output level of phonological encoding in speech production (for a discussion about the locus of the priming effect see also Schiller, 2000, p. 525).

The results of Ferrand et al. (1996, 1997) are often quoted as evidence supporting the notion that the syllable (either as a chunk or as a structure or both) is a unit involved in the retrieval of phonological forms in speech production. However, recent research revealed that the syllabic effects reported by Ferrand and colleagues are not reliable. The first set of studies that failed to replicate the syllabic effects was conducted in Dutch by Schiller (1998). Further research has revealed no syllabic effects in either of the two languages tested by Ferrand et al. (1996, 1997). Brand et al. (2003) and Bonin, Peereman, and Schiller (reported in Schiller et al., 2002) failed to replicate the effect in French, and Schiller (1999, 2000) failed to do so in English. Interestingly, in these studies, the magnitude of the priming effect increased with the length of the prime, independently of the syllabic match or mismatch between the prime and the target. This has been coined the *segmental overlap effect*. The syllabic effect has also been shown to be elusive in languages with clear syllable boundaries such as Spanish (Schiller et al., 2002). Although the reason for the discrepancy between Ferrand et al.'s (1996, 1997) results on the one hand and Brand et al.'s (2003) as well as Schiller's (1998, 1999, 2000) results on the other hand is unclear, these data at least question the extent to which we can use the syllable effect obtained with the masked priming paradigm to support the assumption that syllabic units are involved in the retrieval of phonological properties in speech production.

In the present paper we further investigate the role of syllabic units in speech production by analyzing the performance of participants in two picture-naming experiments. In these experiments, we increased the probability of getting a syllable priming effect by manipulating two variables that have not been manipulated before: a) the stimulus onset asynchrony (SOA) between target and prime presentation, and b) the visibility of the prime.

There are at least two reasons for why the syllable priming effect may be elusive. The first has to do with the level at which syllabic units may play a role during phonological encoding and the SOA between prime and target used in the previous experiments. Following Levelt's model, one may argue that syllabic effects only arise when the prime taps into late stages of the target's phonological encoding. This is because in Levelt's model syllables are not stored in the lexicon but are computed as a result of a syllabification process, that is, when previously selected segments are assigned to slots provided by metrical frames. Therefore, if the prime were to have an effect on the phonological properties of the target at early stages of its processing, no syllabic effects were to be expected. In contrast, one may assume that only by presenting the prime at the right moment in time (that is, at the end of the syllabification process), would one be able to observe syllabic effects. To this end, we explore the possibility of detecting a syllabic effect at different SOAs between prime and target. Primes were presented 200 ms before the picture (SOA –200), simultaneously with the picture (SOA 0), or 200 ms after the picture (SOA +200). In the previous studies by Ferrand et al. (1996,1997) and Schiller (1998, 1999, 2000), the SOAs were between –45 ms and –60 ms. Note that the manipulation of prime-target SOA has already been found useful to study the time course of phonological encoding (e.g., Meyer & Schriefers, 1991).[1]

The second and more important reason for why syllabic effects in the masked priming paradigm are unstable may have to do with the visibility of the primes. In the experiments discussed above, primes were presented for a very brief period of time (45 ms or 60 ms) and they were masked. It is possible that under visually constrained conditions (brief masked prime exposure, as e.g., in Ferrand et al., 1996, 1997; Schiller, 1998, 1999, 2000) the prime is sometimes only processed partially (e.g., instead of the whole prime *bab*, participants only process *ba*, and instead of the whole prime *ba*, participants only process *b*). Alternatively, participants may only process the consonants, but not the vowels (Berent & Perfetti, 1995). If partial processing of the prime were the case, the probability of observing syllabic effects would be much reduced. This is because the intended syllabic matching between prime and target would be lost. Interestingly, in this scenario one should still expect that longer primes (e.g., CV[C]; potentially non-processed segments in square brackets) speed up naming latencies more than shorter primes (e.g., C[V]) — the length effect — which is exactly what Schiller (1998, 1999, 2000) found in Dutch and English. Experiment 2 was designed to test this hypothesis. In that experiment, we increased the probability that participants fully process the primes by increasing the prime exposure duration and by removing the masks.

## Experiment 1: Picture Naming with Masked Primes at Different SOAs

Experiment 1 tested the effect of CV, CVC, and control primes on CV and CVC picture targets (e.g., *pi.lot* and *pic.nic*). Both target types had clear syllable boundaries (see Derwing, 1992; Treiman & Danis, 1988 for empirical evidence). Each target was paired with three primes: CV primes corresponded to the first two letters of the picture name (e.g., *pi — pilot*), CVC primes consisted of the first three letters of the picture name (e.g., *pil — pilot*), and control primes were composed of three non-linguistic characters (e.g., *%&$ — pilot*). Visual orthographic rather than auditory primes were employed because it is well-known from earlier research that those primes activate phonological representations within 30–40 ms in masked priming (e.g., Ferrand & Grainger, 1993, 1994; Perfetti & Bell, 1991). Primes were presented at three SOAs relative to the picture's onset (−200 ms, 0 ms, +200 ms). The syllable-priming hypothesis predicts that CV targets should be named faster when presented with CV primes as compared to control or CVC primes. CVC targets should only show priming when preceded by CVC primes but not when preceded by CV primes.

### *Method*

*Participants.* Eighteen native English speakers were tested individually. Most of them were undergraduates at Harvard University.

*Materials.* There were 32 black-on-white line drawings of common objects, sixteen for each target category, i.e., CV and CVC (see Appendix). Picture names were approximately equal in terms of frequency of occurrence and length measured in number of CV-slots. This is important because participants had to name the pictures (but never read aloud their names). Picture names all corresponded to monomorphemic bisyllabic English nouns stressed on the first syllable. All targets had unambiguous syllable boundaries. Syllable boundaries were determined according to the Maximal Onset Principle (MOP; Kahn, 1976; Selkirk, 1982) and the Branching Rhyme Constraint (BRC; Kager, 1989). The MOP states that intervocalic consonants are affiliated with the onset of the following syllable as long as this does not violate the phonotactic constraints of the language or the BRC. The BRC requires English (but, for instance, also Dutch and German) rhymes to minimally consist of a short vowel plus a consonant or of a long vowel. For CV targets such as *tiger*, there is only one intervocalic consonant, i.e., /g/. English allows all consonants except for /ŋ/ to occupy the onset position, and therefore the syllable boundary may fall after the first vowel. Since the vowel in *tiger* is tense (long), the BRC is also satisfied. For CVC targets, there are two intervocalic consonants. However, phonotactic constraints do not permit certain clusters to occur in onset position (e.g., /pk/ as in *napkin* or /nd/ as in *candle*). In those cases, the syllable boundary falls between the two consonants. Clusters such as /st/ as in *jester* are permitted as onsets by the phonotactics of English. However, the syllabification *je.ster* would violate the BRC because the vowel in the first syllable is lax (short). Therefore, the syllable boundary has to fall between the two intervocalic consonants as well to satisfy the BRC.

*Design*. Participants received one learning block and two practice blocks in which all the pictures were presented, followed by three test blocks. Over the course of the three test blocks, all targets appeared once in each of the three priming conditions. There was an equal number of trials from each SOA in each test block. Items were randomized individually for each participant and each block with the following constraints: Identical targets were separated by at least 15 trials, and the same target type and prime type were not repeated more than once in a row.

*Procedure*. Each trial consisted of four visual stimuli, which were presented in rapid succession. First, a forward pattern mask (i.e., ####) was presented for 500 ms in the center of the screen. The forward mask was immediately substituted by the prime, which appeared for 45 ms in lower-case (e.g., pi). After the prime presentation, a backward pattern mask (i.e., ####) was presented in the same location for 15 ms. Depending on the SOA, the target picture appeared in the center of the screen either 200 ms before, simultaneous with, or 200 ms after prime onset. When target and prime were presented at the same time (SOA 0), prime and mask appeared in a white rectangle superimposed on the target, ensuring that participants could still recognize the pictures. Targets remained on the screen until a response was given or maximally for 2000 ms. Masks and prime were presented (on a computer screen with a refresh rate of 70 Hz) in a non-proportional font (Courier), subtending less than two degrees of visual angle from a viewing distance of 60 cm. Participants were instructed to focus on a fixation point that appeared at the beginning of each trial in the center of the screen and to name the target as quickly and as accurately as possible. The presence of the prime was not mentioned. Naming latencies were measured by means of a voice key (connected to a microphone), which was activated at the onset of target presentation. Erroneous responses (responses exceeding 2000 ms, speech errors, or mouth clicks that triggered the voice key) were excluded from the analyses.

### *Results*

ANOVAs were run with Target Structure (CV or CVC), Prime Structure (CV, CVC, or control) and SOA (−200, 0, or +200) as independent variables. Separate analyses were carried out with participants ($F_1$) and items ($F_2$) as random variables. In Table 1, we report the mean reaction times per condition. Since there were only 2.1% errors in Experiment 1, errors were not analyzed.

The main effect of the factor Prime Structure ($F_1(2, 34) = 42.6$, $MSE = 3047.8$, $p < .001$; $F_2(2, 60) = 68.5$, $MSE = 1765.8$, $p < .001$) was significant. Naming latencies were fastest following CVC primes, somewhat slower in the CV priming condition, and slowest in the control condition. That is, the more linguistic material contained in the prime, the faster the naming latencies. Furthermore, naming latencies were independent of Target Structure ($F_1 < 1$; $F_2 < 1$). Importantly, the interaction between Prime Structure and Target Structure, which would indicate the existence of a syllabic effect, was not significant ($F_1 < 1$; $F_2 < 1$).

The main effect of the SOA was significant ($F_1(2, 34) = 24.0$, $MSE = 2310.6$, $p < .001$; $F_2(2, 60) = 19.6$, $MSE = 2497.7$, $p < .001$). The only factor that inter-

**Table 1.** Mean Naming Latencies (in ms) in Experiment 1

| | SOA | | | | | |
|---|---|---|---|---|---|---|
| | SOA −200 | | SOA 0 | | SOA +200 | |
| | Target Structure | | | | | |
| **Prime Structure** | **CV** | **CVC** | **CV** | **CVC** | **CV** | **CVC** |
| %$& (control) | 606 | 608 | 571 | 577 | 570 | 582 |
| CV | 539 | 545 | 515 | 515 | 579 | 565 |
| CVC | 482 | 492 | 592 | 496 | 581 | 558 |
| Δ (CV – CVC) | 57 | 53 | 23 | 19 | −2 | 7 |

acted with SOA was Prime Structure ($F_1(4, 68) = 21.8$, $MSE = 1434.8$, $p < .001$; $F_2(4, 120) = 13.0$, $MSE = 2154.4$, $p < .001$). Importantly, the triple interaction between SOA, Prime Structure and Target structure was not significant ($F_1(4, 68) = 2.1$, $MSE = 557.9$, n.s.; $F_2 < 1$), indicating that the syllabic interaction was not present at any SOA. Post-hoc analyses revealed that CV and CVC primes led to shorter naming latencies than control primes at SOA −200 (CV: $F_1(1, 17) = 24.3$, $MSE = 1522.0$, $p < .001$; $F_2(1, 31) = 23.7$, $MSE = 2405.9$, $p < .001$; CVC: $F_1(1, 17) = 52.9$, $MSE = 2441.6$, $p < .001$; $F_2(1, 31) = 79.5$, $MSE = 2937.4$, $p < .001$) and SOA 0 (CV: $F_1(1, 17) = 10.5$, $MSE = 363.4$, $p < .005$; $F_2(1, 31) = 26.2$, $MSE = 2331.5$, $p < .001$; CVC: $F_1(1, 17) = 21.3$, $MSE = 458.7$, $p < .001$; $F_2(1, 31) = 61.8$, $MSE = 1797.0$, $p < .001$). Also, CVC primes led to faster naming latencies than CV primes at the same two SOAs (SOA −200: $F_1(1, 17) = 24.6$, $MSE = 1131.7$, $p < .001$; $F_2(1, 31) = 22.6$, $MSE = 2636.2$, $p < .001$; SOA 0: $F_1(1, 17) = 8.9$, $MSE = 153.5$, $p < .01$; $F_2(1, 31) = 5.7$, $MSE = 1296.3$, $p < .05$), indicating that the longer the prime, the larger the magnitude of the priming effect regardless of Target Structure. No differences among the primes were observed at SOA +200 (all $F$s $< 1$).

*Discussion*

The results of this experiment are clear-cut. The matching between the structure of the prime and that of the first syllable of the target does not modulate naming latencies. That is, syllabic effects are absent regardless of the asynchrony between prime and target. Instead, the length of the prime affected naming latencies (the longer the prime, the faster the naming latencies) if the prime was presented before the target or simultaneously with the target. This experiment was designed to explore whether or not the failure to observe syllabic effects with this paradigm could be attributed to a wrong selection of the asynchrony between prime and target. The results give a negative answer to that question. That is, syllabic effects are not present in this paradigm, no matter whether the prime is presented before, at the same time as, or after the target.

In the introduction, we put forward another reason for why obtaining syllabic effects may be so difficult with the masked priming paradigm. We argued that under constrained visual conditions, in some proportion of the trials the visually masked primes might not be fully processed. For example, the prime *pi* may be partially processed to an extent that only the segment *p* was able to produce an effect. Therefore, the expected syllabic effect of the prime *pi* could not arise, since that prime is not processed as an entire syllable. The same is true for CVC primes such as *pic*. In this case, it may be that the prime was encoded as *pi*, and therefore this prime might be facilitating the retrieval of the syllable *pi* in a CV word, such as *pi.lot*, but not the expected retrieval of the syllable *pic* in CVC words, such as *pic.nic*. Alternatively, consonants may be processed faster than vowels (Berent & Perfetti, 1995) which would have a similar effect. If this was the reason for the lack of syllabic effects in Experiment 1, increasing the probability of full processing of the prime should also increase the probability of obtaining a syllabic effect. In Experiment 2, we introduce two different manipulations to make the primes more visible.

## Experiment 2: Picture Naming with Unmasked Primes at Different SOAs

### *Method*

*Participants.* Eighteen English native speakers from the same population as in the first experiment participated in Experiment 2 (nine in each condition).

*Materials, Design, and Procedure* were the same as in Experiment 1 except for the prime exposure conditions. In Experiment 2, primes were presented under unmasked conditions, i.e., there were no pattern masks. In one condition (Condition 45 ms), participants saw the prime for 45 ms; in another condition (Condition 105 ms), the prime was presented for 105 ms. The prime was clearly visible in both conditions.

### *Results*

ANOVAs were run with Target Structure (CV or CVC), Prime Structure (CV, CVC, or control), Condition (45 ms or 105 ms), and SOA (−200, 0, or +200) as independent variables (see Tables 2 and 3). Separate analyses were carried out with participants ($F_1$) and items ($F_2$) as random variables. The only significant effect in the error analyses (5.1% errors) was an interaction between SOA and Prime Structure.

Naming latencies were faster in Condition 105 ms than in Condition 45 ms ($F_1(2, 32) = 117.1$, $MSE = 1903.3$, $p < .001$; $F_2(2, 60) = 87.0$, $MSE = 4617.5$, $p < .001$). There was a main effect of Prime Structure ($F_1(2, 32) = 181.2$, $MSE = 1287.9$, $p < .001$; $F_2(2, 60) = 132.8$, $MSE = 3098.8$, $p < .001$). Naming latencies were similar for CV and CVC targets as revealed by the non-significant effect of Target Structure ($F_1 < 1$; $F_2 < 1$). The syllabic interaction of Target Structure and Prime Structure was not significant ($F_1 < 1$; $F_2 < 1$).

**Table 2.** Mean Naming Latencies (in ms) in Experiment 2 (Condition 45 ms)

| | SOA | | | | | |
|---|---|---|---|---|---|---|
| | SOA −200 | | SOA 0 | | SOA +200 | |
| | Target Structure | | | | | |
| **Prime Structure** | **CV** | **CVC** | **CV** | **CVC** | **CV** | **CVC** |
| %$& (control) | 654 | 622 | 650 | 647 | 676 | 672 |
| CV | 533 | 553 | 592 | 582 | 673 | 647 |
| CVC | 471 | 480 | 570 | 562 | 656 | 645 |
| Δ (CV – CVC) | 62 | 73 | 22 | 20 | 17 | 2 |

**Table 3.** Mean Naming Latencies (in ms) in Experiment 2 (Condition 105 ms)

| | SOA | | | | | |
|---|---|---|---|---|---|---|
| | SOA −200 | | SOA 0 | | SOA +200 | |
| | Target Structure | | | | | |
| **Prime Structure** | **CV** | **CVC** | **CV** | **CVC** | **CV** | **CVC** |
| %$& (control) | 619 | 615 | 562 | 591 | 611 | 604 |
| CV | 492 | 524 | 522 | 522 | 583 | 570 |
| CVC | 444 | 444 | 491 | 487 | 596 | 585 |
| Δ (CV – CVC) | 48 | 80 | 31 | 35 | −13 | −15 |

The main effect of SOA was significant ($F_1(2, 32) = 117.1$, $MSE = 1903.3$, $p < .001$; $F_2(2, 60) = 87.0$, $MSE = 4617.5$, $p < .001$). SOA interacted with Prime Structure ($F_1(4, 64) = 54.7$, $MSE = 895.1$, $p < .001$; $F_2(4, 120) = 20.8$, $MSE = 3880.4$, $p < .001$). CVC primes yielded significantly shorter naming latencies than CV primes at SOA −200 ($F_1(1, 17) = 123.0$, $MSE = 320.6$, $p < .001$; $F_2(1,31) = 23.0$, $MSE = 6047.7$, $p < .001$) and SOA 0 ($F_1(1, 17) = 24.1$, $MSE = 275.5$, $p < .001$; $F_2(1, 31) = 19.3$, $MSE = 1238.1$, $p < .001$). No differences between the two primes were observed at the positive SOA ($F_1 < 1$; $F_2 < 1$). The interaction of Prime Structure and Target Structure was not significant at any SOA, suggesting that the syllabic interaction was not present at all. The factor Condition interacted only with the SOA factor ($F_1(2, 32) = 8.1$, $MSE = 1903.3$, $p < .001$; $F_2(2, 60) = 16.5$, $MSE = 1838.3$, $p < .001$). None of the other interactions were significant, suggesting that the effects of Target Structure and Prime Structure are similar for Condition 45 ms and Condition 105 ms.

*Discussion*

This pattern of results is very similar to that observed in Experiment 1. The three main results of the previous experiment have been replicated in Experiment 2:

First, we did not observe a trace of a syllabic interaction in Condition 45 ms nor in Condition 105 ms. Second, CVC primes were more powerful in speeding up naming latencies than CV primes (segmental overlap effect). Third, the segmental overlap effect is only present when the primes are presented before the target picture or simultaneously with the target.

## General Discussion

The most compelling experimental evidence supporting the notion that syllables are involved in speech production is the syllable priming effect observed by Ferrand et al. (1996, 1997). However, such an effect has been shown to be rather elusive (e.g., Brand et al., 2003; Schiller, 1998, 1999, 2000; Schiller et al., 2002). In the present study, we explored whether or not we could gather more evidence for the existence of such a syllable priming effect by manipulating two variables that we thought could increase the probability of observing such an effect: (a) the stimulus onset asynchrony between prime and target, and (b) the visibility of the prime.

In Experiment 1, we covered a range of SOAs between prime and target, hoping to tap different stages of phonological encoding. In Experiment 2, we increased the prime exposure duration and we removed the masks in order to make the primes more visible and presumably more efficient. However, and despite these efforts, no syllabic effects were observed in the two experiments. That is, naming latencies were independent of whether or not the prime corresponded to the first syllable of the target. However, in both experiments primes were processed to the extent to which they could affect naming latencies, as revealed by the fact that CVC primes facilitated naming more than CV primes at SOA −200 and SOA 0. These results are in line with the results obtained by Schiller (1998, 1999, 2000) where an increase of the number of shared segments resulted in an increase of the magnitude of the priming effects. Considering these results together it seems reasonable to conclude that the lack of syllabic priming effects in this paradigm cannot be attributed to either the partial processing of the primes or the selection of wrong SOA values. The fact that we observed sizeable priming effects (i.e., the segmental overlap effects) demonstrates that our design was powerful enough to detect a syllabic priming effect if such an effect were to exist.

It is possible that the syllable priming effect is elusive because the effects reported with this paradigm do not have their locus at the phonological level. However, we think that this is not the case and that actually the locus of these effects is probably the phonological level. In a recent study, Schiller (submitted) tested whether form-priming effects obtained with masked priming are orthographic or phonological in nature in Dutch. Target words (e.g., *cirkel* 'circle') were preceded by either orthographically related masked primes (e.g., *cortex* 'cortex'), phonologically related masked primes (e.g., *sector* 'sector'), orthographically *and* phonologically related masked primes (e.g., *censuur* 'censorship'), or unrelated masked primes (e.g., *lasso* 'lasso'). Results revealed significant facilitation effects for the phonologically and the orthographically as well as phonologically related conditions relative to the unrelated condition. The orthographically related condition, however, was not different from the unrelated condition. Furthermore, there was no difference between the phonologically related and the orthographically and phonologically related conditions. Therefore, these Dutch data suggest that masked form-priming effects are (mainly) located at the phonological level. This view is supported by the fact that a form-priming effect is obtained with picture targets, i.e., when no orthographic information is available (Schiller, 1998, 2000; Schiller et al., 2002).

Another possible reason one may think of to explain why syllabic effects were not present in our experiments refers to some properties of the materials used. English is relatively inconsistent with respect to the pronunciation of letter strings (Martensen, Maris, & Dijkstra, 2000). Most cases of inconsistency in the correspondence between graphemes and phonemes arise from irregularities in the mapping of vowels. For example, a CV prime such as *ba* when pronounced in isolation would yield the pronunciation /beɪ/ as in *baker* (/beɪkər/), but never /bæ/ as in *basket* (/bæskət/). This is because English does not allow lax (short) vowels in open syllables. Similarly, CVC primes such as *bak* or *bas* would yield the pronunciations /bæk/ or /bæs/ (as in *basket*), respectively, but not /beɪk/ (as in *baker*) or /beɪs/, respectively. That is, one and the same grapheme <a> has several phonemic values depending on whether it occurs in open or closed syllables. Experimental evidence from a pronunciation task reported elsewhere (see Schiller, 2000, footnote 8) suggests that native speakers of English have a strong tendency to assign a tense (long) pronunciation to vowels in open syllables (e.g., CV), whereas vowels in closed syllables generally receive lax (short) pronunciations (see also Ryan, Ostergaard, Norton, & Johnson, 2001).

Interestingly, if priming effects were entirely due to phonological matching between prime and target, one would expect the naming of CV targets to be facilitated more when presented with a CV prime than when presented with a CVC prime. That means, a syllabic priming effect should have occurred. This is because the pronunciation of the vowel depends on the syllabic structure and the same syllabic structures have similar vowel pronunciations. Nevertheless, our data suggest that *bak* yielded more priming than *ba* for the target *baker* (in spite of the phonological mismatch between *bak* and *baker* when pronounced in isolation).

However, following this argument, the question is how we can explain the pattern of results reported here, i.e., the segmental overlap effect? One possible solution would be that the orthographic units of the prime activate a whole set of possible phonological units. For example, the orthographic unit *ba* would activate the phonological syllables /beɪ/, /bæ/, etc. The amount of activation may vary depending on the frequency with which a graphemic unit is pronounced as a specific phonemic unit (see Berndt, Reggia, & Mitchum, 1987 for a frequency database of grapheme-to-phoneme correspondences in English). As we already proposed, under such circumstances it is conceivable that *bab* yielded more priming for the target *baby* than *ba*, although the default pronunciation of *bab* does not match the pronunciation of *baby* (see also Schiller, 2000; Schiller et al., 2002 for more detailed discussion of this *multiple activation account*). The idea that a specific grapheme activates several phonemes resembles a proposal by Brown and Besner (1987) who suggested that the assembly of any English consonant yields a single output, whereas the assembly of vowels results in multiple outputs (see also Stone, Vanhoy, & Van Orden, 1997).

Another explanation for the existence of segmental overlap effects refers to the possibility that the priming effects are based on the consonantal letters alone. That is, a CVC prime would always be more efficient than a CV prime because it has one additional consonant. We have no independent grounds to reject this hypothesis for English. Berent and Perfetti (1995) proposed a two-cycles model of phonology assembly for reading in which consonant and vowel planes are two distinct constituents in the assembled code. In a first cycle, consonants are assembled in a fast and relatively automatic process. The assembly of vowels takes place in a second cycle by slower, controlled processes. The segregation of consonants and vowels at the graphemic level has been suggested, for instance, by Caramazza and Miceli (1990) and is supported by neuropsychological data (Caramazza, Chialant, Capasso, & Miceli, 2000; Caramazza, & Miceli, 1990; Cubelli, 1991). The two-cycles model predicts that brief target exposure, as was the case in the experiments reported in this study, limits the amount of processing and will increase the chances of tapping only the first cycle. Berent and Perfetti (1995) provide extensive empirical evidence for the distinct time course of consonant and vowel assembly, and the two-cycles model could possibly account for the priming effects obtained in the current study as well without invoking a multiple activation account (but see Lukatela & Turvey, 2000).[2]

The present results have one main implication. Our data suggest that we cannot use the syllable priming effects obtained with this paradigm to support the idea that syllabic units are encoded during phonological encoding. Recall that the syllable priming effect observed by Ferrand et al. (1996, 1997) was the most compelling evidence for the existence of syllabic units in phonological encoding. However, the amount of studies that failed to replicate the syllable priming effect in various languages (Brand et al., 2003; Schiller, 1998, 1999, 2000; Schiller et al., 2002; for an overview see Schiller, in press) is now considerably large. Therefore, we believe that the use of such an effect to support the existence of syllabic units in speech production should be abandoned. Experimental evidence showed in a series of experiments that even in French the syllable priming effect is elusive (see also Schiller et al., 2002). This is an important conclusion because it should force us to search for other techniques to address the role of syllabic units in speech production (see for instance Cholin et al., 2004).

Given the repeated failure to obtain syllabic effects with the masked priming paradigm, and the fact that the paradigm itself seems to be sensitive to units of phonological encoding, one may be tempted to conclude that syllables are not functional units in speech production. However, there are at least three reasons to believe that such a conclusion would be premature.

First, there are some results (Costa & Sebastián-Gallés, 1998; Ferrand & Segui, 1998; Sevald et al., 1995) suggesting that syllables play a role during phonological encoding as abstract structures into which the phonological segments are inserted during a process of segment-to-frame association (see Levelt & Wheeldon, 1994; but see also Roelofs & Meyer, 1998).

Second, it is possible that the (masked) priming paradigm is not a good paradigm to investigate syllabic priming effects in phonological encoding. Ferrand et al. (1996, 1997) are the only authors who have obtained a syllable priming effect so far, and even an exact replication of the Ferrand et al. (1997) study failed (Schiller, 2000, Experiment 1A). One may argue that the effects observed with this paradigm have nothing to do with phonological encoding. However, the paradigm is sensitive to phonological primes in general, as demonstrated by the fact that the length of the primes affected the magnitude of the priming. Note that recently, we were able to find syllabic effects with a different experimental paradigm, namely preparation instead of priming (Cholin et al., 2004). The preparation paradigm was introduced by Meyer (1990, 1991) and supposedly affects the rightward prosodification of phonological words, whereas priming results in the activation of segments in memory (Levelt et al., 1999, p. 25). There is independent evidence that priming and preparation paradigms tap different levels of processing in phonological encoding (Roelofs, 2002).

Third, although linguistic and psycholinguistic descriptions are not necessarily completely overlapping, linguistic theory is clearly simplified by postulating syllabic units (e.g., Blevins, 1995). There are linguistic processes that make reference to the syllable, such as syllable final devoicing (e.g., in Dutch or German) and syllable initial aspiration of plosives (e.g., in English); these processes imply that syllabic units may exist.

However, it may also be argued that syllables are not used as phonological planning units in phonological encoding, but are rather just a consequence of the open-close articulatory modulation associated with the production of vowels (opening movements) and consonants (closing movements) (MacNeilage, 1998). Therefore, syllables may just be an epiphenomenal consequence of the necessity of generating a maximally pronounceable and perceivable stream of sounds, i.e., an alternation of vowels and consonants, as suggested by Ohala (1998). Further research is clearly needed to determine whether or not syllables play a role during phonological encoding. The evidence collected with the masked priming paradigm in favor of the syllable, as a functional unit in phonological encoding, should be carefully reconsidered.

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## Notes

1. Note, however, that the time course of phonological priming effects seems to be different when using unattended primes (as in the picture-word interference paradigm) versus using subliminal primes (as in the masked priming paradigm). Picture-word interference studies typically do not reveal phonological priming effects at negative SOAs (e.g., Damian &

Martin, 1999; Schriefers, Meyer, & Levelt, 1990; but see Jescheniak & Schriefers, 2001; Starreveld, 2000), whereas masked priming studies — in which the prime is presented before the target, i.e., at slightly negative SOAs — usually yield phonological priming effects (e.g., Ferrand & Grainger, 1994; Ferrand et al., 1996, 1997; Schiller, 1998, 1999, 2000). A speculation about the reason(s) for this falls beyond the scope of this paper.

**2.** However, data from Dutch potentially sheds some doubt on the two-cycles model. In Experiment 5 of the study by Schiller (1998), the amount of overlap between the masked prime and the target word was manipulated from no segmental overlap to complete segmental overlap. Thus, there was also a C and a CV priming condition. If the priming effects were driven by consonants alone, one would not expect any significant differences between these two conditions. However, the results showed significantly more priming for CV primes than for C primes (independent of the target type), even under extreme visual masking conditions. This outcome suggests that vowels also provide some benefit.

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## Appendix

Stimulus Materials in Experiments 1 and 2

| **Target structure** | |
|---|---|
| CV targets | CVC targets |
| baby | monkey |
| tiger | doctor |
| tuba | jester |
| moped | magnet |
| cable | picnic |
| silo | banjo |
| baker | pencil |
| bison | basket |
| pilot | pelvis |
| ruler | donkey |
| raven | window |
| totem | helmet |
| razor | sandal |
| robot | cactus |
| zebra | candle |
| table | napkin |

*Note.* The mean frequency of occurrence per one million word forms (COBUILD corpus) was 29.4 for the CV targets and 22.8 for the CVC targets as determined by the CELEX lexical database for English (Baayen, Piepenbrock, & Gulikers, 1995). Also, length measured in number of CV-slots (according to CELEX) was similar for CV (5.6) and CVC (5.8) targets.