Phonological encoding of single words: In search of the lost syllable

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Abstract

Syllables seem to be very salient units in speech perception and production. Yet, experimental evidence for the role of a syllabic unit in production is scarce. In this paper, we first review the support for the existence of syllabic units in speech production. Especially relevant in this area are results that were obtained with the masked priming paradigm. We show that using this paradigm with comparable methodologies has led to contradictory results in the past. This may have to do with the fact that mostly Germanic languages were tested. Here, we will mention data from English demonstrating that the visibility of the prime (masked or unmasked) and the time between prime and target presentation (i.e., stimulus onset asynchrony or SOA) are not crucial for obtaining the syllable priming effect. However, we will also present data from Spanish, i.e. a Romance language, showing that the failure to replicate the syllable priming effect is not restricted to Dutch and English. Finally, we present two experiments from French, the second of which seems to show a weak syllabic effect. Taken together, these results do not support the view that the syllable plays an independent role in phonological encoding.

1. The origin of the syllable priming hypothesis

The syllable plays an important role in modern approaches to phonology (see Blevins, 1995 for a recent overview). Some phenomena such as syllable-initial aspiration of plosives in English or syllable-final devoicing of obstruents in Dutch or German can easily be described with reference to the syllable as a unit (see Kenstowicz, 1994). However, syllables may be useful not only as phonological but also as psycholinguistic units. In language acquisition, for example, syllables are important units in the process of acquiring the phonological system of a language (Gerken, 1994; Liberman, Shankweiler, Fischer, & Carter, 1974; Wijnen, Krikhaar, & Den

Os, 1994; for an overview see Macken, 1995). Recently, Levelt, Schiller, and Levelt (2000) described the process of acquiring syllable structure in Dutch using *Optimality Theory* (OT). It was shown that Dutch children between one and three years of age followed a pattern of syllable structure acquisition that increased in complexity and could be captured by an OT grammar.

Also, for the adult speaker/listener syllables may play an important role. For instance, in a seminal paper, Mehler, Dommergues, Frauenfelder and Segui (1981) observed that when participants were asked to monitor words for certain sequences of sounds, they were faster to do so when the target sequence (e.g., /pal/) corresponded to the first syllable of a carrier word (e.g., *pal.mier*) than when it did not match the first syllable (e.g., *pa.lace*; dots are used to indicate syllable boundaries throughout this paper). CV targets were responded to faster in carrier words that started with a CV syllable (hereafter *CV words*) than in carrier words starting with a CVC syllable (hereafter *CVC words*), and CVC targets yielded faster reaction times (RTs) for CVC words than for CV words, even though the entire CVC phoneme string is present in both types of units. This *syllable match effect* was interpreted as evidence for the existence of the syllable as a prelexical speech segmentation unit.

This effect has been replicated in many other Romance languages but not in Germanic languages (see Cutler, 1997 for a summary). In English, for instance, stress is important for the perception of words (a stress-rhythm language; Cutler, & Norris, 1988), while moras play a crucial role for the perception of Japanese (a mora-rhythm language; Otake, Hatano, Cutler, & Mehler, 1993). In speech production, evidence for syllabic units is more scarce than in speech perception (see Schiller, 1998 for a review). However, in two recent papers, Ferrand and co-workers claimed to have found syllable priming effects in French (Ferrand, Segui, & Grainger, 1996) and English (Ferrand, Segui, & Humphreys, 1997) speech production. These authors presented a visually masked letter string before a target word or picture that had to be named (see Figure 1). The letter string was orthographically and/or phonologically related to the target but participants were generally not able to recognize it. Masking the primes has the advantage of minimizing the possibility of task-specific strategic effects. In one condition, the prime corresponded to the first syllable of the target name. In the other condition, it was one segment longer or shorter than the target's first syllable. Ferrand et al. (1996, 1997) found that when the prime matched the first syllable of the target (e.g., *ca* – CA.ROTTE '*carrot*' or *car* – CAR.TABLE '*school bag*'), naming latencies were significantly shorter than when the prime did not match the first syllable (e.g., *ca* – CAR.TABLE or *car* – CA. ROTTE).

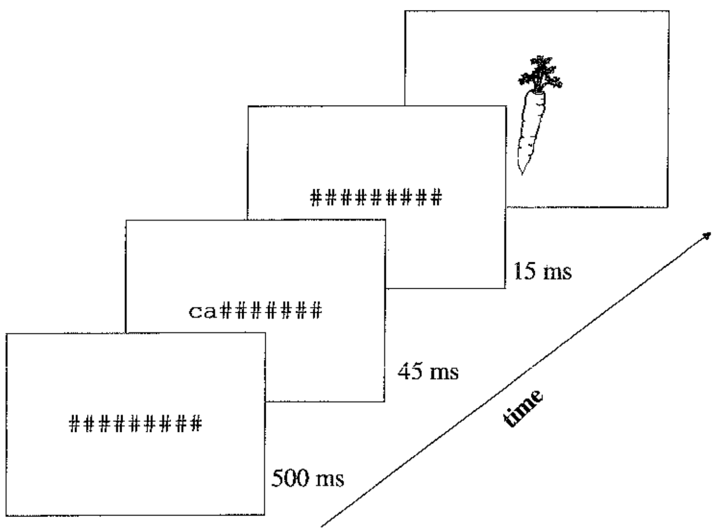

Figure 1: Illustration of one experimental trial in the experiment: Each trial comprises four different screens. First, the forward pattern mask is presented for 500 ms. Then, the prime is in view for a brief amount of time, e.g., 45 ms. The prime is immediately followed by the backward pattern mask for 15 ms. Finally, the target is presented.

This *syllable priming effect* was accounted for in terms of the (pre)-activation of syllabically structured phonological output units.[1] "Sublexical orthographic units that are activated upon prime presentation will send activation directly to the syllabic output units thus facilitating the pronunciation of any target stimulus that shares the same syllable units" (Ferrand et al., 1996, p. 714). However, this explanation presents some problems, at least for English.

Given the irregular grapheme-to-phoneme correspondence in English, it is not clear how orthographic syllables are able to (pre)activate the appropriate phonological syllables for speech output in English. To give an example, how does the speech production system "know" that the visual prime *de* corresponds to the phonemic sequence /dɪ/ when *de.tect* is the target or to the phonemic sequence /dɛɪ/ when *de.but* is the target? Both words are bisyllabic and have final stress. The model Ferrand et al. (1996, 1997; see also Ferrand & Grainger, 1994) presented to account for their syllabic effect does not solve the problem of spelling inconsistency in English.

2. Does the syllable priming hypothesis also hold for Dutch?

Schiller (1998) attempted to replicate the syllable priming effect in Dutch. Dutch is a Germanic language that is phonologically very similar to English. However, Dutch is characterized by a very transparent spelling system. Dutch distinguishes short and long vowels. Vowel length is marked in Dutch in the following way: In open syllables, vowels receive a long pronunciation (e.g., *de.ler* /delər/). In closed syllables, pronunciation depends on the spelling: Double marking of the vowels corresponds to a long pronunciation (e.g., *deel.tje* /deltjə/), single marking means short pronunciation – and slightly more open articulation of the vowel (e.g., *del.ta* /dɛlta/). On the basis of the transparent spelling in Dutch, syllabic priming effects are to be expected: *de* /de/ should prime the CV word *de.ler* /delər/ but not the CVC word *del.ta* /dɛlta/, and for the prime *del* /dɛl/ the reverse should be true. However, this is not what Schiller (1998) obtained. He never found a syllable priming effect across a series of five experiments. Instead, he consistently obtained *segmental overlap effects* – the longer the overlap in segments between prime and target, the shorter the naming latencies. Syllabic overlap did not play a separate role (e.g., the letter string *del* primed both the CV word *de.ler* ("divisor") and the CVC word *del.ta* ("delta") significantly more than the letter string *de*). This effect could not be due to residual visual overlap between the masked letter prime and the target because the effect was not only obtained with words but also with pictures. In Experiment 5 of that study, Schiller (1998) showed that for six-letter words identity priming yielded shorter RTs than having only the first five letters of the word. This in turn was more efficient than having the first four letters of the word, etc. Having only the onset of a word still yielded significant priming effects as compared to a control condition in which no linguistic information about the target word was contained. Schiller (1998) accounted for this effect by the (pre-) activation of phonological segments facilitating their retrieval when the target has to be encoded phonologically for production. He suggested that the visually masked primes first activate orthographic units, but these do not send activation directly to articulatory output units. Instead, they activate sublexical phonological units, which correspond to segments.

There are at least two unpublished dissertations that also looked at masked syllable priming. Evinck (1997) used the same methodology and materials as Ferrand et al. (1996) but could not replicate their syllable priming effect in French. Boelhouwer (1998) aimed at obtaining a syllable priming effect in Dutch, but also without success. These two additional failures to replicate further demonstrate the weakness of the syllable priming effect.

3. The syllable priming effect is in fact a segmental priming effect – Further evidence from English

To further investigate the segmental priming effect, more experiments were carried out in English. As we mentioned earlier, Ferrand et al. (1997) reported a syllable priming effect for English, although this effect was unambiguously obtained in only one of the five experiments in that study. However, it was never obtained in a series of seven new experiments (Schiller, 1999, 2000). Instead, using the same methodology as in the Ferrand et al. (1997) study, the segmental overlap effect (Schiller, 1998) was replicated in English several times using different materials and tasks (word and picture naming). To account for the priming effect in a language picture naming). To account for the priming effect in a language like English where the grapheme-to-phoneme mapping variability is very high, a *multiple activation account* was invoked: Orthographic segments activate a whole set of possible phonological correspondences. The amount of activation may possibly be weighted by the frequency with which a particular grapheme is pronounced as a particular phoneme. The more segments from the target are activated, the larger the priming effect. On this account, the letters "pi" prime *pilot* (/paɪlət/) and *pillow* (/pɪləʊ/) to the same extent and the letters "pil" prime the same targets significantly more.

All the studies referred to above used slightly negative stimulus onset asynchronies (SOAs) and subliminal primes to investigate the syllable priming effect, that is, the target picture or word appeared on the screen a small number of milliseconds after the prime was presented on the screen. SOA and visibility of the prime are crucial, at least in masked priming. Therefore, it may be that slight variations of these two factors have large effects on the outcome of the experiment. We tried to investigate these potential effects systematically. First, we investigated the influence of presenting the prime at different moments in time relative to the presentation of the target picture or word. That is, we varied the SOA over a range from negative to positive SOAs. Second, we manipulated the visibility of the prime from masked (subliminal visibility) to unmasked (full visibility). In the following, we describe two experiments that were carried out in English.

In the first experiment, we tested the effect of CV, CVC, and control primes on naming of CV and CVC picture targets (for details about the procedure and design see Schiller and Costa, submitted). Masked primes were presented at three SOAs relative to picture onset (–200 ms, 0 ms, +200 ms) (see Figure 2). At SOA – 200 ms, the prime appears on the screen 200 ms before the target. The reverse condition holds at SOA +200 ms, i.e., first the target appears on the screen, 200 ms later the prime. At SOA 0ms, the prime is presented superimposed on the target, i.e., they are presented simultaneously, but the prime is replaced after some milliseconds by the backward mask. The predictions were clear: The syllable priming hypothesis predicts that CV targets should be

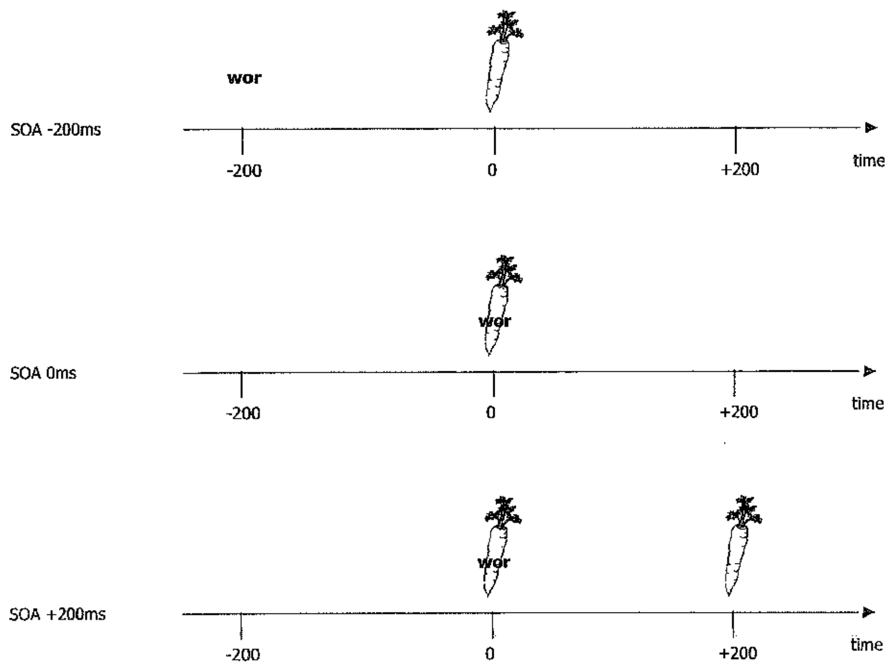

Figure 2: Illustration of the three SOAs used in the experiment: At SOA –200 ms (upper panel), the prime precedes the presentation of the target picture by 200 ms. At SOA 0 ms (middle panel), the prime is presented superimposed on the target. Finally, at SOA +200 ms (lower panel), the prime appears superimposed on the target after the target alone had been in view for 200 ms.

named faster when presented with CV primes as compared to CVC or control primes (Ferrand et al., 1997). CVC targets should only show priming when preceded by CVC primes but not when preceded by CV or neutral primes. The segmental overlap hypothesis (Schiller, 1998, 1999, 2000), however, predicts that CVC primes should be more effective than CV primes independent of the target structure. Both of these predictions are valid at least for short negative SOAs (such as –200 ms) and SOA 0 ms. At later, positive SOAs (such as +200 ms) the prime is no longer presented before the target. According to Levelt's model of phonological encoding (Levelt & Wheeldon, 1994; Levelt, Roelofs, & Meyer, 1999), syllables are not stored in the lexicon but are computed at later stages of phonological encoding as the result of a syllabification process.

Therefore, this theory might predict a syllable structure effect at SOA +200 ms even though it does not for earlier prime presentation, since one may assume under this theory that syllabic priming effects can only emerge if the prime is presented late enough in the process of producing the target.

Three main results were observed (for a detailed analysis of the results see Schiller and Costa, submitted). First, there was an effect of length of prime in the RTs: The longer the prime, the faster the RTs. Second, the priming effect was modulated by the SOA. Priming decreased from SOA –200 ms to SOA 0 ms, until it finally disappeared at SOA +200 ms. Third, and most importantly, no syllabic interaction was observed; that is, the magnitude of the priming effect was independent of whether or not the prime matched the structure of the first syllable of the target. Why did we not find a syllabic priming effect? A possible answer could be that the visually masked primes were not fully processed.

It is possible that under constrained visual conditions in some proportion of the trials the primes were not fully processed. For instance, the prime *pi* may be partially processed to an extent that only the segment *p* was able to produce an effect. If this is true, the expected syllabic effect of the prime *pi* could not arise, since that prime would not be 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*. If this was the reason for the lack of syllabic effects in that experiment, increasing the probability of full processing of the prime should also increase the probability of obtaining a syllabic effect.

In the second experiment, we made the primes clearly visible instead of masked. For SOAs of −200 ms and 0 ms, the results of the second experiment replicate the observations of the first one. For SOA +200 ms, a reliable priming effect (without segmental overlap effect) was obtained in the second, but not in the first experiment.

The outcome of these two experiments suggests that, first, the lack of syllabic effects cannot be attributed to partial processing of the primes since even with clearly visible primes the syllabic effect was not found. Second, we have shown that a syllabic effect did not arise even when we tried to tap into different stages of phonological encoding by varying the SOA. Third, when primes and target shared some segments, a priming effect was found, the magnitude of which depended exclusively on the length of the prime (at least at SOA −200 ms and SOA 0 ms). 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.

4. Is the syllable priming effect a phenomenon of syllable-timed languages?

An interim summary of the data would state then that in Dutch and English, segments but not syllables can be primed using the masked priming paradigm. However, the question of whether the syllable priming effect in French (Ferrand et al., 1996) remained valid was still open, and also whether or not it holds for other Romance languages. Romance languages are claimed to have a prosodic structure that relies on syllables as primary rhythmic units to a larger extent than Germanic languages such as Dutch or English, which are generally claimed to have a stress-based rhythm (Abercrombie, 1967; Pike, 1946). Therefore, it could be the case that there is a correlation between the primary prosodic unit of a language and the presence of a syllable priming effect as there is in perception (Cutler, 1997).

The precise nature of such a correlation in models of phonological encoding (e.g., Dell, 1986, 1988; Levelt et al., 1999), however, is not clear. Levelt's model, for instance, assumes that the metrical frame is built or retrieved (depending on the language and the status of the word) at the same time that the segments are retrieved. Segments are then serially assigned to the metrical frame on the basis of syllabification rules. This general architecture holds for *all* languages, whether syllable-timed or stress-timed. Thus, there is no principled difference in phonological encoding of syllable-timed languages that would make the syllable priming effect expected in French in this model. It could be that when syllables play a role in the rhythmic organization of a language, they can be primed, whereas syllables cannot be primed if they are not very salient units in a particular language because they do not contribute to the rhythm.

Spanish is another syllable-timed language. Therefore, data from Spanish may be interesting with respect to the syllable priming effect. If the syllable priming effect is a property of syllable-timed languages, the effect should emerge in Spanish. Colomé and Costa carried out two word-naming experiments with masked syllable primes to investigate the syllable priming effect in Spanish. The results of these experiments are reported below.

4.1 Experiment 1: Word Naming in Spanish with 28 ms prime

4.1.1 Method

Participants. Eighteen undergraduate students at Barcelona University took part in the third experiment. All of them came from Spanish monolingual families. They received extra course credit for their participation.

Materials. Two sets of 36 words were employed (see Appendix A). In both sets, half of the stimuli were bisyllabic and half were trisyllabic words. In Set A, words were grouped in pairs that shared the first three segments (e.g., *mono* 'monkey' – *monja* 'nun'). In one of the groups, the first three segments corresponded to the initial syllable (e.g., *mon.ja*). In the other group, they consisted of the first syllable and the onset of the second one (e.g., *mo.no*). In Set B, stimuli could not be paired, but there was the same number of CV and CVC initial syllables both within the bisyllabic and the trisyllabic words. All stimuli were presented in white and centred on a black screen.

Procedure. Participants were tested individually in a soundproof booth, using a very similar procedure to the one employed by Ferrand et al. (1996, 1997). They were invited to fixate the hash marks that would appear at the beginning of each trial and to name the word that would replace them as soon as possible and without making errors. Each trial had the following structure: First, a forward mask consisting of hash marks was displayed for approximately 500 ms. It was immediately followed by the prime in lower case, which remained on the screen for 28 ms. Afterwards, a backward mask appeared for 14 ms. Then, the target word was presented, in capital letters to reduce the visual overlap between prime and target. The prime-target SOA was therefore –42 ms. The target remained in view until the participant responded or for a maximum of 2000 ms. Finally, there was a blank screen for 1000 ms before next trial started. Reaction times (RTs) were measured from target onset. The EXPE program (Pallier, Dupoux, & Jeannin, 1997) was used to display the stimuli and record the RTs. Participants were never informed about the existence of the primes. Before the experimental session started, they received a training block where all the targets appeared preceded by the neutral prime.

Design. All words were presented three times, once with each type of prime. Primes could be either the first two (CV) or the first three (CVC) letters of the target. In addition, there was a neutral prime consisting of the characters %&$. All primes were followed by a number of hash marks to equate the length in letters of prime and target word. Three blocks of stimuli with pauses between them were created with the following restrictions: a) no more than four consecutive stimuli of the same set; b) maximally two primes of the same condition in a row. We also checked that the two words in a pair of Set A did not appear consecutively.

4.1.2 Results and Discussion

RTs less than 300 ms or greater than 1600 ms were excluded from the analysis. These trials, together with ones where participants stuttered or produced a non-linguistic sound before the response and where the computer failed to record the response, constituted only 1.3 % of the trials, so no error analysis was conducted.

Mean naming latencies are summarized in Table 1. We used these data to run two ANOVAs with three factors: Set (A or B), Prime Type (CV or CVC) and Target Structure (CV or CVC). F values are reported separately for participants (F_1) and items (F_2).

The main effect of Set was significant only by participants ($F_1(1,17) = 6.89$, $p < .05$; $F_2(1,68) = 1.08$, n.s.). None of the interactions of this variable, either with Prime Type ($F_1(1,17) = 3.16$, n.s.; $F_2(1,68) = 2.47$, n.s.) or Target Structure (both Fs < 1), nor the three-way interaction between Set, Prime Type and Target Structure ($F_1(1,17) = 1.17$, n.s.; $F_2 < 1$) reached significance, so we decided to pool both sets in the following comparisons. Neither the main effect of Target Structure nor its interaction with Prime Type were significant (all Fs < 1). Finally, the main effect of Prime Type was only significant by participants ($F_1(1,17) = 9.06$, $p < .01$; $F_2(1,68) = 1.18$, n.s.). Both CV and CVC primes differed significantly from the neutral condition ($t_1(17) = 8.77$, $p < .01$; $t_2(71) = 4.50$, $p < .01$ and $t_1(17) = 8.63$, $p < .01$; $t_2(71) = 5.53$, $p < .01$, respectively).

Table 1: Mean naming latencies for Experiment 1 in ms (with % errors).

		Target Structure	
Set	Prime Type	CV	CVC
A	CV	457 (0.0)	457 (1.6)
	CVC	454 (1.6)	461 (1.2)
	Neutral	464 (1.4)	471 (1.9)
	Δ (CV−CVC)	3	−4
B	CV	464 (0.7)	466 (1.4)
	CVC	459 (0.9)	458 (1.4)
	Neutral	474 (1.4)	474 (1.2)
	Δ (CV−CVC)	5	8

4.2 Experiment 2: Word Naming in Spanish with 42 ms prime

Experiment 1 did not show any sign of a syllable priming effect. Instead, Prime Type showed a tendency towards a segmental overlap effect: CVC primes were on average more efficient than CV primes. However, this effect was only significant by participants but not by items.

One reason for why this effect did not reach significance might be that the prime exposure duration was too short. Schiller (1998, 1999, 2000) used slightly longer prime exposure durations than in Experiment 1. Presenting the prime too briefly may render it ineffective. Therefore, we decided to run another experiment in Spanish with a slightly longer prime exposure duration.

4.2.1 Method

Participants. Twenty-four undergraduate students from the same population described in the previous experiment participated in Experiment 2.

Materials, Procedure, and Design. Everything remained the same as in Experiment 1 except for the exposure time of the prime, which was extended to 42 ms (i.e., one screen refresh cycle more than in the previous experiment). Thus, the SOA between prime and target was –56 ms in Experiment 2.

4.2.2 Results and Discussion

Naming latencies shorter than 300 ms and longer than 1600 ms were excluded. Altogether, only 1.7% of the total data were considered errors, so we did not run an error analysis. As for the RTs, Table 2 shows the mean naming latencies for each of the conditions. An ANOVA was conducted again with three main factors: Set (A or B), Prime Type (CV or CVC) and Target Structure (CV or CVC).

The main effect of Set was significant only by participants – but not by items – ($F_1(1,23) = 6.75$, $p < .05$; $F_2(1,68) = 2.17$, n.s.) and neither the interactions with Target Structure (both Fs < 1) or Prime Type ($F_1(1,23) = 2.80$, n.s.; $F_2(1,68) < 1$) nor the three-way interaction between Set, Target Structure and Prime Type reached significance (both Fs < 1), so we decided to run a joint analysis of the material from both Sets.

The difference between the two Target Structures was significant only by participants ($F_1(1,23) = 6.53$, $p < .05$; $F^2(1,68) < 1$). The interaction of Target Structure and Prime Type was not significant (both Fs < 1), so, again, there was no syllable priming effect.

The main effect of Prime Type, however, was significant ($F_1(1,23) = 11.82$, $p < .01$; $F_2(1,68) = 5.11$, $p < .05$), indicating that the longer the prime was, the easier it was to name the target, irrespective of syllabic structure. That is, a segmental priming effect was obtained. Furthermore, we conducted two planned comparisons to check whether both CV and CVC primes differed significantly from the neutral condition; t values were significant by participants and items ($t_1(17) = 7.81$, $p < .01$; $t_2(71) = 7.55$, $p < .01$ and $t_1(17) = 8.99$, $p < .01$; $t_2(71) = 9.23$, $p < .01$, respectively).

Table 2: Mean naming latencies for Experiment 2 in ms (with % errors).

		Target Structure	
Set	Prime Type	CV	CVC
A	CV	490 (1.2)	495 (2.8)
	CVC	488 (2.1)	492 (2.1)
	Neutral	509 (1.6)	511 (2.3)
	Δ (CV−CVC)	2	3
B	CV	499 (0.9)	505 (1.6)
	CVC	493 (1.6)	494 (1.2)
	Neutral	518 (1.4)	511 (1.9)
	Δ (CV−CVC)	6	11

The outcome of this experiment did not show any sign of a syllable priming effect. Instead, segmental priming effects were obtained. The Spanish results from two experiments speak clearly against the syllable priming hypothesis. That is, although Spanish is generally considered to rely on syllables as rhythmic units, no syllabic priming effects were obtained. Instead, the overall pattern across both experiments more closely resembles the segmental priming effect: The longer the prime, the shorter the RTs. However, it could be the case that Spanish is not the best example of a syllable-timed language. Sebastián-Gallés, Dupoux, Segui, & Mehler (1992), for instance, could replicate the perceptual syllable monitoring effect from French (Mehler et al., 1981) with Spanish materials only when participants performed an additional memory task, whereas Bradley, Sánchez-Casas, and García-Albea (1993) replicated the original French perceptual result for Spanish without this additional procedure. This may be taken as an indication that Spanish is not as syllable-timed as French. Note that we understand the phonological distinction of syllable vs. stress-timed as a continuum rather than a categorical classification.

Furthermore, the Spanish experiments have one drawback, namely that only word naming but no picture naming experiments were reported. Generally speaking, qualitative differences have never been found between word and picture naming in masked priming (Ferrand et al., 1996; Schiller, 1998, 1999, 2000). Only quantitative differences have been obtained, namely that form priming effects in picture naming are usually larger than in word naming, as seen in the current experiments. Nevertheless, it may be the case that the word-naming task is carried out without accessing the lexicon, e.g., via non-lexical grapheme-to-phoneme conversion (GPC) rules. Such a strategy is especially likely in an orthographically transparent language like Spanish. The failure to replicate the syllable priming effect in Spanish may be a consequence of such a strategy, if syllabic units are only involved in phonological encoding when access to the word form lexicon is involved, but not when targets are produced purely on the basis of GPC rules. Therefore, two picture naming experiments were carried out; however, not in Spanish but in French. French is a prototypical syllable-timed language. If the syllable priming effect holds for so-called syllable-timed languages, we should observe it in French. Furthermore, since we employed a picture-naming task, the target cannot be produced on the basis of GPC rules. If the syllable priming effect is contingent on accessing the lexicon, we should observe it. The results of the French experiments are reported below.

4.3 Experiment 3: Picture naming in French with 34 ms prime

French is the prototype of a syllable-timed language. Bonin, Peereman, and Schiller carried out a series of picture naming experiments in French using visually masked primes that either matched or mismatched the first syllable of the target's name. The methodology of these experiments closely followed the original Ferrand et al. (1996) experiments.

4.3.1 Method

Participants. Twenty-six students of the University Blaise Pascal from Clermont-Ferrand (France) participated in the third experiment. All were native speakers of French and had normal or corrected-to-normal vision. Participants received course credits for taking part in the experiment.

Materials. The materials consisted of 48 bi- and trisyllabic French words corresponding to pictorial objects (see Appendix B). All items were grouped into pairs beginning with the same three segments but differing in syllable structure (CV or CVC). The items were matched for number of letters, number of syllables, and frequency of occurrence. The objects were presented as simple line drawings. Materials partially overlapped with the materials used by Ferrand et al. (1996). However, Ferrand et al. (1996) used only ten pairs.

Procedure. The procedure was similar to the one described for the previous experiments. The presentation of the trials was controlled by PsyScope. Pictures were used as targets. Prime exposure duration was 34 ms (i.e., two screen refresh cycles of the monitor used in the Clermont-Ferrand laboratory).

Design. The design was similar to the one described in Experiment 1 except that no control prime condition was included.

4.3.2 Results and Discussion

The results are summarized in Table 3. There were no significant effects in the errors. RT analysis revealed that the main effect of Prime Type (CV or CVC) was only marginally significant by participants ($F_1(1,25) = 3.74$, $p < .06$) and not significant by items ($F_2(1,46) = 1.99$, n.s.). The main effect of Target Structure (CV or

CVC) was not significant (both Fs < 1), and the interaction of Prime Type and Target Structure was not significant either. That is, there was no syllable priming effect.

Table 3: Mean naming latencies for Experiment 3 in ms (with % errors).

	Target Structure	
Prime Type	CV	CVC
CV	864 (8.2)	852 (8.7)
CVC	871 (7.7)	875 (6.6)
Δ (CV−CVC)	−7	−23

The results of this experiment are somewhat inconclusive, since neither syllabic effects nor segmental overlap effects were observed. However, RTs are considerably longer (> 860 ms) than in the original Ferrand et al. (1996) study (approximately 730 ms). This may simply be a consequence of the fact that different and more pictures were used in this study than in the Ferrand et al. (1996) study. However, participants might have generated an internal deadline and not responded before that deadline, which would result in a ceiling effect and rather long RTs. As a result, any differences between the priming conditions may have been lost. Furthermore, we should consider the possibility that the primes were not effective using such a short prime exposure duration. In the first Spanish experiment (see above) as well as in the studies by Evinck (1997) and Boelhouwer (1998) very brief prime exposure durations (28 ms) were used also, but no effects were found. Therefore, a second experiment was carried out using a slightly longer prime exposure duration. Furthermore, it was stressed in the instructions that speed was important for the responses.

4.4 Experiment 4: Picture naming in French with 51 ms primes

4.4.1 Method

Participants. Twenty-eight students from the same pool as described in the previous experiment took part in Experiment 4.

Materials, Procedure, and Design. The same procedure, materials, and design were used as in the previous experiment except that the prime exposure duration was extended to 51 ms and participants were asked to stress speed when responding.

4.4.2 Results and Discussion

The results of Experiment 4 are summarized in Table 4. The error analysis did not reveal any significant results. In the RT analysis, neither the main effects of Target Structure nor of Prime Type were significant (all Fs < 1). However, it can be seen from Table 4 that CV primes were more effective for CV targets than for CVC targets and that for CVC primes the situation was reversed. This looks like a syllable priming effect, although the interaction between Prime Type and Target Structure is only significant by items ($F_1(1,27) = 3.64$, $p = .067$; $F_2(1,46) = 4.25$, $p = .044$). One reason why the syllable priming effect is weaker here than in the original study by Ferrand et al. (1996) may be the difference in magnitude of the effects: There is a big difference between the effects obtained here (9 and 16 ms) and in the Ferrand et al. (1996) study (35 and 49 ms). This is surprising if one considers that the prime exposure duration was longer here (51ms) than in the Ferrand et al. (1996) study (29ms). When we used a similar prime exposure duration (34ms; Experiment 3), we obtained inconclusive results (see above). However, Experiment 4 showed that under certain circumstances it may be possible to obtain a syllabic effect in French speech production using masked priming.

Table 4: Mean naming latencies for Experiment 4 in ms (with % errors).

	Target Structure	
Prime Type	CV	CVC
CV	737 (6.1)	745 (4.9)
CVC	746 (5.5)	729 (6.1)
Δ (CV−CVC)	−9	16

General Discussion

The present results have several theoretical implications. Our data suggest that one 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. The English results referred to in this study support the segmental overlap effect, the Spanish results (Experiments 1 and 2) also support the segmental overlap effect, and the French results (Experiments 3 and 4) provide some weak evidence for the syllable priming hypothesis. None of the four experiments reported in this paper resulted in a clear syllable priming effect, but one of them resulted in a clear, i.e. statistically significant, segmental overlap effect. Shall we then reject the assumption that syllables are represented during speech production? There are at least four reasons to believe that such a conclusion would be premature.

First, there are some results (Costa, & Sebastián, 1998; Ferrand, & Segui, 1998; Sevald, Dell, & Cole, 1995) suggesting that syllables are at play 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 latter study failed (Schiller, 2000). It is unclear, though, what the problem with this paradigm is. 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. Therefore, we have to conclude that if a syllable priming effect exists at all, it is extremely unstable.

Third, although linguistic and psycholinguistic descriptions do not necessarily completely overlap, linguistic theory is clearly simplified by postulating syllabic units (e.g. Kenstowicz, 1994, p. 250). 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), and these processes imply that syllabic units exist.

Fourth, it is possible that the relevant phonological units involved in speech production depend on language-specific properties of the language being spoken. This cross-linguistic hypothesis finds some support in the results presented in this paper. The fact that the syllabic effect arises only for a clear so-called syllable-timed language (i.e. French) may suggest that the syllable is a relevant representational unit in some languages but not in others.

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 needed to determine under which conditions 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 of English should be carefully reconsidered. However, we provided some evidence that under appropriate masking conditions the syllable may play a role in French speech production.

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Notes

1 An input account was excluded on the basis of lexical decision experiments that did not show any facilitation (i.e., a syllable priming effect) under the same priming conditions.

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Appendix A (Spanish materials)

SET A:

Target Structure

	CV	*CVC*
1.	bo.lo (skittle)	bol.sa (bag)
2.	ca.sa (house)	cas.co (helmet)
3.	pi.no (pine tree)	pin.za (clothes peg)
4.	ma.no (hand)	man.cha (stain)
5.	ba.la (buttlet)	bal.sa (raft)
6.	co.no (cone)	con.cha (shell)
7.	pa.la (spade)	pal.co (box)
8.	ro.sa (rose)	ros.ca (thread)
9.	mo.no (monkey)	mon.ja (nun)
10.	sa.le.ro (salt cellar)	sal.chi.cha (sausage)
11.	ca.la.mar (squid)	cal.ce.tín (sock)
12.	pa.no.cha (corncob)	pan.te.ra (panther)
13.	mo.ne.da (coin)	mon.ta.ña (mountain)
14.	ba.na.na (banana)	ban.de.ra (flag)
15.	ca.me.llo (camel)	cam.pa.na (bell)
16.	pa.lo.ma (pigeon)	pal.me.ra (palm)
17.	ve.ne.no (poison)	ven.ta.na (window)
18.	ma.no.pla (mitten)	man.za.na (apple)

SET B:

Target Structure

	CV	*CVC*
1.	ca.ma (bed)	fal.da (skirt)
2.	va.so (glass)	dis.co (record)
3.	ve.la (candle)	mos.ca (fly)
4.	co.la (queue)	tan.que (tank)
5.	me.sa (table)	bom.ba (bomb)
6.	ra.mo (bouquet)	ban.co (bench)
7.	pe.sa (weight)	rom.bo (rhombus)
8.	ra.na (frog)	ces.ta (basket)
9.	cu.na (cradle)	cal.vo (bald)
10.	co.ne.jo (rabbit)	pas.ti.lla (pill)
11.	gu.sa.no (worm)	lám.pa.ra (lamp)
12.	pe.lo.ta (ball)	cas.ti.llo (castle)

13. co.me.ta (kite)	pes.ta.ña (eyelash)
14. te.ne.dor (fork)	pis.ci.na (swimming pool)
15. ca.mi.sa (shirt)	can.gu.ro (kangaroo)
16. ma.le.ta (suitcase)	ban.de.ja (tray)
17. cá.ma.ra (camera)	pis.to.la (pistol)
18. pe.lu.ca (wig)	ves.ti.do (dress)

Appendix B (French materials)

(Targets are listed in French orthography except where phonemic transcription is necessary to show syllable structure.)

SET A:

Target Structure

CV	*CVC*
so.leil (sun)	sol.dat (soldier)
ca.rotte (carrot)	car.touche (cartridge)
se.rinque (syringe)	ser.pent (snake)
ce.rise (cherry)	cer.veau (brain)
fi.let (net)	fil.tre (filter)
ga.rage (garage)	gar.çon (boy)
ma.ri.o.nette (puppet)	mar.gue.rite (daisy)
pa.lace (palace)	pal.mier (palm tree)
ca.ca.huette (peanut)	cac.tus (cac.tus)
ca.puche (capuchin)	cap.sule (seal)
vo.lant (steering wheel)	vol.can (volcano)
ca.ra.bine (carbine)	car.table (satchel)
ca.ra.vanne (caravan)	car.net (note book)
ca.sier (canterbury)	cas.tor (beaver)
ma.rin (sailor)	mar.mite (pot)
ba.leine (whale)	bal.con (balcony)
pi.scine (swimming pool) /pi.sin/	pis.to.let (pistol)
bi.son (bison)	bis.cuit (cracker) /bis.kwi/
ca.rafe (carafe)	car.pette (rug)
ma.ra.cas (maracas)	mar.cas.sin (young wild boar)
ca.ril.lon (carillon)	car.quois (quiver)
ha.ri.cot (bean)	har.pon (harpoon)
ba.ril (keg)	bar.be.le (barbed wire)
ca.lu.met (calumet)	cal.mar (squid)