Is the phonological encoding of English words syllabically structured?

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ABSTRACT

Four experiments are reported which investigate the *syllable priming effect* in English [2]. In Experiment 1, pictures had to be named. Visually masked letter primes preceded the targets and either matched the first syllable of the target picture's name or were one segment shorter or longer than the target's first syllable. Additionally, there was a neutral control prime. Results showed that targets were named fastest when the primes had the largest segmental overlap with the target independent of syllable structure. Experiment 2 replicated this result with word targets, and in Experiment 3 target words were grouped into pairs again yielding the same result. Experiment 4 is a replication of Experiment 2 with a longer prime exposure duration. These results contradict the *syllable priming hypothesis* but support the alternative *segmental overlap hypothesis* [13].

1. INTRODUCTION

Most psycholinguistic models agree that syllables play an important role in speech perception and speech production (for speech perception see [1] for speech production see [2], [3], [4], [5]). Experimental evidence for this view comes mainly from off-line data. In metalinguistic tasks, for instance, syllables are one of the linguistic units that are preferably manipulated (see [6] for English and [7] for Dutch). Furthermore, speech errors generally obey the syllable position constraint, i.e., onsets exchange with onsets, codas exchange with codas, etc. [8] (see [9] for a critical review).

However, there are also some on-line tasks that provided evidence for the use of syllables as psycholinguistic processing units. [10] reported clear syllabic effects in French speech perception. In a syllable monitoring task participants were asked to monitor either for a particular CV or a CVC syllable (C stands for consonant, V for vowel). Auditory target words either began with a CV or with a CVC syllable. Their data showed that participants were faster to monitor for *pa* in *pa.lace* than in *pal.mier* and they were faster for *pal* in *pal.mier* than in *pa.lace* (dots indicate syllable boundaries). Since their target words could be grouped into pairs that shared the first three segments, the effect may be explained by the difference in syllable structure. This *syllable match effect* was taken as evidence that the syllable plays an important role in French speech comprehension.

2. EARLIER EXPERIMENTS

[11] found an equivalent of this syllable match effect in speech production tasks using masked syllable priming. They obtained reliable facilitation in picture, word, and nonword naming when prime and target overlapped in their first syllable relative to a condition where they shared a string of segments of equal length that was one segment shorter or longer than the first syllable. However, this *syllable priming effect* disappeared in lexical decision, i.e., a task that can be performed without the output phonology of the target. According to these authors, this is strong evidence that the syllable is not only a functional processing unit in French speech perception but also in production.

Recently, [12] found a syllable priming effect in English word naming: Production of CVC targets was significantly faster when preceded by CVC primes than when preceded by a neutral prime. Compared to this neutral prime, no facilitation was observed when targets were preceded by CV primes. Targets that included ambisyllabic consonants were equally facilitated by CV and CVC primes, when compared to a neutral control condition. Most importantly, significant priming effects for CV targets only occurred in the CV priming condition but not when targets were preceded by CVC targets. The authors concluded that the syllable also constitutes a unit of speech production in English, just as in French. [13], however, could not find such an effect in Dutch, although English and Dutch are phonologically quite similar. Both languages do not allow for short vowels to appear in open syllables and both languages contain ambisyllabic consonants. In Dutch, however, there was no sign of a syllable priming effect in word and picture naming across five experiments. In contrast, in all experiments naming latencies were shortest when the segmental overlap between prime and target was largest. Therefore, the Dutch results were accounted for by a *segmental overlap hypothesis*.

3. PRESENT EXPERIMENTS

The present paper re-examines the syllable priming effect in English because there were some shortcomings in the original study by [12]: First of all, [12] did only carry out word naming experiments in

English, but no picture naming. However, since words can be read aloud by the application of grapheme-to-phoneme conversion rules, the word form representations in the mental lexicon do not have to be accessed. In contrast, to name a picture, all relevant stages of the speech production process presumably have to be accessed [14]. Second, the materials were not very well controlled: In the crucial Experiment 5, fifteen of the 24 target words were pseudo-prefixed, and the syllable boundary fell behind this pseudo-prefix. Participants may have noticed the structural relationship among the target words in this experiment. And third, the design of the crucial experiment allowed participants to engage in a strategy. Once participants noticed that all target words in Experiment 5 started with a CV syllable, they may have been able to use this information strategically to trigger their articulatory responses in the following way: Primes that are compatible with the syllable structure of the targets, i.e., CV primes, facilitated naming, whereas primes that were incompatible (i.e., CVC) or neutral, did not (for a more detailed discussion of this criticism see [13], [15], [16]).

All experiments reported here employed the masked priming technique. In this technique, a visually masked prime is presented before the target (a word or a picture) appears on a computer screen. The prime exposure duration is very short which prevents subjects from visually identifying the primes. Subjects are required to name the target as soon as it appears on the screen. Because subjects cannot identify the prime, they are unable to produce any expectations about the target after the prime has been presented. Therefore, this technique is generally considered to reduce strategic effects to a minimum.

3.1. Experiment 1

In Experiment 1, pictures had to be named. All 48 picture names corresponded to bisyllabic, monomorphemic English words with lexical stress on the first syllable. Three different types of targets were used: Picture names starting with a CV syllable (e.g., PI.LOT), picture names that started with a CVC syllable (e.g., PIC.NIC), and picture names that contained an ambisyllabic consonant (CV[C]; ambisyllabic consonants appear between square brackets, e.g., PI[LL]OW). Pictures were preceded by visually masked letter primes that corresponded to the first syllable (CV or CVC) of the picture name or were one segment shorter or longer than its first syllable (e.g., pi – PI.LOT or pil – PI.LOT; pi – PIC.NIC or pic – PIC.NIC; pi – PI[LL]OW or pil – PI[LL]OW). Additionally, a control prime (e.g., %&$ - PI.LOT; %&$ - PIC.NIC; %&$ - PI[LL]OW) served as a baseline condition. Primes were presented for 30 ms. Figure 1 shows the sequencing and timing of the stimuli on the screen. Participants were required to name the target picture as soon as it appeared on the computer screen. Naming latencies were measured with a voice key.

The syllable priming hypothesis predicts faster reaction times in the syllable match condition than in the syllable mismatch condition. That is, the picture of the PILOT, for instance, should be named faster when preceded by "pi" than when preceded by "pil". No facilitation is predicted for "pil", i.e., statistically this condition should not differ from the baseline condition. The segmental overlap hypothesis, on the contrary, predicts the shortest naming latencies for the condition where prime and target have the largest segmental overlap, i.e., for the CVC priming condition. The syllabic structure of the target does not play a role in this account.

The results of Experiment 1 showed that naming latencies were shorter in the CVC priming condition (596 ms) than in the CV priming condition (609 ms) independent of the syllabic structure of the target, i.e., there was no interaction between target type and priming condition. Naming latencies were longest in the neutral control condition (615 ms). The difference between the CV and the CVC priming condition was significant for all three target conditions (for CV targets: $p < .05$ for both t values; for CVC targets: $p < .05$ for both t values; for CV[C] targets: $p < .05$ for both t values).

The results of Experiment 1 did not reveal any sign of a syllable priming effect. Instead, the obtained facilitation effects support the segmental overlap hypothesis because the priming effects increased with increased segmental overlap between prime and target.

3.2. Experiment 2

Experiment 2 tested whether the segmental overlap effect found in Experiment 1 could be replicated using a different task, i.e., word naming. Since [12] applied the word naming task in all of their experiments, it may be the case that the syllable priming effect in English is restricted to this task. The same targets that were used in Experiment 1 as pictures were also used in Experiment 2, but now there were presented as printed words in the center of the screen. Target words were preceded by the same visually masked primes as in Experiment 1. Participants' task was to read the words aloud as fast and as accurately as possible.

The results are similar to those obtained in Experiment 1. The main effect of priming condition was significant ($p < .001$ for both F values), but not the interaction between target type and priming condition indicating the lack of a syllable priming effect. Target words preceeded by CVC primes were named fastest (437 ms), followed by the CV priming condition (441 ms), and by the neutral control condition (449 ms). Planned comparisons revealed that the difference between the CV and the CVC priming condition was significant ($p < .05$ for t_1 and $p < .10$ for t_2).

type of stimulus	syllable match condition	syllable mismatch condition	neutral control condition	exposure duration on the screen
forward mask	`######`	`######`	`######`	500 ms
prime	`pic%%%`	`pi%%%%`	`%&$%%%`	30 ms
backward mask	`######`	`######`	`######`	15 ms
target	`PICNIC`	`PICNIC`	`PICNIC`	max. 2000 ms

Figure 1. Sequencing of the stimuli in the masked priming paradigm used in the experiments of this study. (In Experiment 1, the targets were pictures, in Experiments 2-4 word targets were used. In Experiment 4, the prime exposure duration was extended from 30 ms to 45 ms.)

The pattern of results is similar to the outcome of Experiment 1. Again, there was no sign of a syllable priming effect. Instead, the data support the segmental overlap hypothesis. To further test the segmental overlap hypothesis, Experiment 3 was carried out in which all target words were grouped into pairs such that they overlapped in the initial three segments. This had the advantage that identical primes could be used for the CV and the CVC targets.

3.3. Experiment 3

In Experiment 3, only CV and CVC targets were used. All word targets could be grouped into pairs and overlapped in the first three letters while being different in syllable structure (e.g., <u>SE.C</u>RET – <u>SEC</u>.TION). The method was comparable to the first two experiments. The same result as in the previous two experiments was obtained: Target words were named slowest in the neutral control condition (472 ms). Both related primes facilitated the naming of the targets, but the CVC primes (462 ms) did more so than the CV primes (465 ms) ($p < .10$ for both t values). This is additional support for the segmental overlap hypothesis using a different set of materials and different subjects.

However, the difference between the CV and the CVC priming condition did not reach significance in this experiment. This had probably to do with the relatively small overall size of the priming effects in the experiments reported so far. We never obtained effects of similar magnitude as those reported by [12]. Therefore, in Experiment 4 prime exposure duration was extended to 45 ms.

3.4. Experiment 4

The prime exposure duration in Experiments 1-3 was very similar to the experiments reported in the [12] study (30 ms). However, the magnitude of the effects was much smaller in the present study than in the original study. Therefore, Experiment 4 was added to show that the size of the priming effect increases with longer prime exposure duration. Primes were presented for 45 ms. Presumably, this resulted in extended processing of the primes and possibly in larger effects. Tests of prime visibility showed that participants were still not able to read the primes, and most participants remained unaware of the presence of the primes.

Experiment 4 was completely identical to Experiment 2 with the exception of the participants and the prime exposure duration: While in Experiment 2 primes were presented for 30 ms, in Experiment 4 they were presented for 45 ms.

As predicted, the nature of the effects remained the same, but the effect size increased. Participants were faster in naming target words that were preceded by CVC primes (430 ms) than in naming targets which were preceded by CV primes (436 ms); the neutral control condition yielded the longest naming latencies (449 ms). These results contradict the syllable priming hypothesis but are in line with the segmental overlap hypothesis.

4. CONCLUSION

As predicted by the segmental overlap hypothesis, the priming effects increased with an increased segmental overlap between prime and target. This result was consistently obtained across four experiments using partially different materials, different tasks, and different participants, indicating that the effect is not artifactual. Furthermore, the results reported above are in line with earlier experiments conducted in Dutch [13]. In contrast, they are incompatible with the syllable priming hypothesis. It may be concluded that not syllables but only segments play a functional role during phonological encoding in speech production in English - just like in Dutch.

Levelt's (see [3], [4], [5]) model of speech production can nicely account for this data pattern.

This model does not assume the representation of syllables in the word form lexicon. Rather, syllables are created "on the fly" during phonological encoding. The creation of syllables occurs at a relatively late stage, namely when previously selected segments, which are only marked for their serial position within a morpheme, are associated with their corresponding metrical frames. Since in the masked priming paradigm the prime is presented *before* the target, it may be hypothesized that this paradigm taps into an early stage of phonological encoding of the target. Presumably, only the segments of the target have been selected at that stage, but the segments have not yet been syllabified. Therefore, segmental priming effects are obtained, but no syllabic effect. Schiller and Costa (in preparation) are currently investigating whether a syllabic priming effect may be obtained when a masked prime is presented at a later point in time relative to the presentation of the target picture. The syllable priming effect in French [11] can be accounted for as an input effect, given the syllabic match effects found in French speech perception (see [13] for details).

[17], [18], [19] implemented Levelt's model of speech production as a computational model called WEAVER (Word-form Encoding by Activation and VERification). WEAVER computes the syllabification of words during the process of phonological encoding. In computer simulations, Roelofs (personal communication) tested the effect of CV and CVC primes that were phonologically related or unrelated to CV and CVC targets. He obtained facilitation effects for the related primes relative to the unrelated primes. However, as in the experiments reported in this paper, facilitation effects were larger with CVC than with CV primes for both types of targets. There was no sign of a syllable priming effect (see [13] for details). Thus, the simulation results obtained from WEAVER are in line with the empirical data from both the experiments in Dutch and in English.

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REFERENCES

[1] Cutler, A. (1995). Spoken word recognition and production. In J. L. Miller & P. D. Eimas (Eds.), *Speech, Language, and Communication* (pp. 97-136). San Diego: Academic Press.

[2] Dell, G. S. (1988). The retrieval of phonological forms in production: Tests of predictions from a connectionist network. *Journal of Memory and Language*, **27**, 124-142.

[3] Levelt, W. J. M. (1989). *Speaking. From intention to articulation*. Cambridge, MA: MIT Press.

[4] Levelt, W. J. M. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition*, **42**, 1-22.

[5] Levelt, W. J. M., Roelofs, A, & Meyer, A. S. (in press). A theory in lexical access in speech production. *Behavioral and Brain Sciences*.

[6] Treiman, R., & Danis, C. (1988). Syllabification of intervocalic consonants. *Journal of Memory and Language*, **27**, 87-104.

[7] Schiller, N. O., Meyer, A. S., & Levelt, W. J. M. (1997). The syllabic structure of spoken words: Evidence from the syllabification of intervocalic consonants. *Language and Speech*, **40**, 103-140.

[8] Shattuck-Hufnagel, S. (1987). The role of word onset consonants in speech production planning: New evidence from speech error patterns. In E. Keller & M. Gopnik (Eds.), *Motor and sensory processing in language* (pp. 17-51). Hillsdale, NJ: Erlbaum.

[9] Meyer, A. S. (1992). Investigation of phonological encoding through speech error analyses: Achievements, limitations, alternatives. *Cognition*, **42**, 181-211.

[10] Mehler, J., Dommergues, J. Y., Frauenfelder, U., & Segui, J. (1981). The syllable's role in speech segmentation. *Journal of Verbal Learning and Verbal Behavior*, **20**, 298-305.

[11] Ferrand, L., Segui, J., & Grainger, J. (1996). Masked priming of word and picture naming: The role of syllabic units. *Journal of Memory and Language*, **35**, 708-723.

[12] Ferrand, L., Segui, J., & Humphreys, G. W. (1997). The syllable's role in word naming. *Memory & Cognition*, **35**, 458-470.

[13] Schiller, N. O. (1998). The effect of visually masked syllable primes on the naming latencies of words and pictures. *Journal of Memory and Language*, **39**, 484-507.

[14] Glaser, W. R. (1992). Picture naming. *Cognition*, **42**, 61-105.

[15] Schiller, N. O. (in press). Masked syllable priming of English nouns. *Brain and Language*.

[16] Schiller, N. O. (submitted). Single word production in English: No evidence for the role of syllables.

[17] Roelofs, A. (1996). Serial order in planning the production of successive morphemes of a word. *Journal of Memory and Language*, **35**, 854-876.

[18] Roelofs, A. (1997a). Syllabification in speech production: Evaluation of WEAVER. *Language and Cognitive Processes*, **12**, 657-693.

[19] Roelofs, A. (1997b). The WEAVER model of word-form encoding in speech production. *Cognition*, **64**, 249-284.