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# Masked Priming of Word and Picture Naming: The Role of Syllabic Units

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A series of word, nonword, and picture naming experiments is reported using the masked priming paradigm with very brief prime exposures. In Experiment 1 naming latencies for both bi- and trisyllabic words were faster when preceded by primes that corresponded to the first syllable than when preceded by primes that contained one letter more or less than the first syllable. Experiment 2 showed syllable priming effects with bisyllabic nonword targets in the naming task. Experiment 3 failed to observe such syllable priming effects with word and nonword targets in the lexical decision task. Finally, Experiment 4 replicated the syllabic priming effects using pictures as targets. These results suggest that the syllable represents a functional unit of output phonology in French. © 1996 Academic Press, Inc.

Reading aloud printed words and naming common objects are two basic human activities that involve a complex combination of perceptual and motor skills. Cognitive psychologists strive to describe the processes and representations underlying such skilled behavior by breaking down the overall task into simpler subcomponents (e.g., perceptual processing, lexical retrieval, articulatory programming). The major difficulty with such an endeavor is the development of adequate experimental and theoretical tools. One very promising experimental technique developed recently in studies of visual word recognition

(e.g., Evett & Humphreys, 1981; Forster & Davis, 1984) involves presenting very briefly a prime stimulus followed immediately by a given target stimulus. This technique, referred to as the masked prime paradigm (due to the use of visual masking procedures) greatly reduces prime visibility and thus the likelihood that subjects detect a relationship between prime and target stimuli. Since the detection of a relationship between the prime and target during the course of an experiment might bias subjects' responses in some way, reducing the likelihood that this will occur therefore reduces the possibility that observed priming effects are due to such strategic biases. The present experiments apply the masked prime technique to the study of word and picture naming in an attempt to determine the role of syllable-sized units in both of these cognitive activities.

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## MASKED PRIMING IN WORD AND PICTURE NAMING

Recently, Ferrand, Grainger, and Segui (1994) reported a series of word and picture naming experiments using a masked priming paradigm with prime exposures brief enough to prevent identification. Ferrand et al. (1994)

found chance-level performance when subjects were asked to judge whether the masked prime word was nominally the same as the target, suggesting that very little precise information about the prime was available for conscious identification. This absence of awareness was taken as clear evidence for the automaticity of the processes under study. Even in such impoverished prime presentation conditions, there is evidence that high-level (e.g., lexical) representations are activated during prime processing and can subsequently affect word and picture naming.

Using this masked priming technique, Ferrand et al. (1994) examined the type of codes that are generated under masking conditions when prime stimuli are words or pronounceable strings of letters. In particular, we demonstrated that the prior presentation of the same word prime facilitated both picture and word naming independently of target frequency. Furthermore, similar effects were obtained using primes that were pseudohomophones of the picture and word targets (see also Ferrand, 1995, for an extension of these results to digit naming). Given that these results were observed in conditions that prevent conscious identification (briefly presented forward and backward masked primes), they are consistent with recent evidence showing that phonological information about a written word becomes available rapidly and automatically (see Berent & Perfetti, 1995; Ferrand & Grainger, 1992, 1993, 1994; Grainger & Ferrand, 1994, 1996; Lukatela & Turvey, 1994; Perfetti & Bell, 1991).

Furthermore, Ferrand et al. (1994) found a marked dissociation in the priming effects obtained with picture and word targets. Picture naming was strongly and reliably facilitated by the prior presentation of a masked pseudohomophone prime, whereas a masked orthographically related nonhomophonic prime failed to facilitate picture naming. On the other hand, word naming was facilitated by the prior presentation of both a pseudohomophone prime and an orthographically related prime. These results suggest that the masked priming of word naming is primarily

sensitive to orthographic prime–target overlap, whereas primed picture naming is primarily sensitive to phonological overlap. In order to capture these results, Ferrand et al. (1994) presented a simple model of picture and word naming. This model introduces a distinction between an orthographic and a phonological lexicon and between sublexical orthographic units and sublexical phonological units (see also Ferrand & Grainger, 1992, 1993, 1994; Grainger & Ferrand, 1994, 1996). Sublexical units activate in parallel both orthographic and phonological word units, whereas picture representations will send activation only directly to the phonological lexicon. The final articulatory output is assumed to depend both on the activity of whole-word units and on sublexical orthographic units. Due to the hypothetical time-course of information flow in this model (determined by its architecture), when reading printed words aloud, the articulatory output will receive activation first from sublexical orthographic units. With picture targets, on the other hand, the articulatory output will receive activation first from whole-word phonological representations. Thus, speeded word naming will be dominated by sublexical orthography, whereas picture naming will be mainly influenced by activity in the phonological lexicon. The dissociation in priming effects obtained with picture and word targets can be given the following interpretation. A briefly presented pseudohomophone prime can activate the corresponding phonological word unit in memory, thus giving rise to facilitation in picture naming, but will result in an even stronger activation of the corresponding sublexical orthographic codes since these are closer to the input. Since according to our model, in word naming the articulatory output receives information from these sublexical orthographic codes before it receives information from lexical codes, it is the orthographic overlap between prime and target that will mainly influence the time to name written word targets. It should be pointed out, however, that the stimuli used by Ferrand et al. (1994) were

only monosyllabic words compared to the bi- and trisyllabic words to be used in the present experiments.

The present research examines more precisely the nature of the representations subserving the observed facilitation effects. In particular, this research examines the possible role of sublexical phonological units, namely syllables, as functional units in word and picture naming, an area that has received little attention as yet. This point is important given that in our previous pseudohomophone experiments we used only monosyllabic items making it impossible to distinguish between lexical and syllabic effects. The present study was designed to find out if the phonological codes that are generated from a masked prime are structured syllabically at some level in the information processing hierarchy. We also want to know at what level(s) of processing syllabic codes are involved in word and picture naming (if they are involved at all).

#### THE SYLLABLE'S ROLE IN NAMING

Over the past decade the syllable has come to enjoy a privileged status as a critical unit in phonology both from a linguistic (e.g., Clements & Keyser, 1983; Fudge, 1969; Kaye, 1989; Selkirk, 1982) and a psycholinguistic (e.g., Cutler, Mehler, Norris, & Segui, 1986, 1992; Levett & Wheeldon, 1994; Mehler, 1981; Mehler, Dommergues, Frauenfelder, & Segui, 1981; Meyer, 1990; Segui, 1984; Segui, Dupoux, & Mehler, 1990) perspective. However, studies examining syllabic effects in word naming in English have yielded rather inconsistent results. For instance, Jared and Seidenberg (1990) hypothesized that if words are broken down into syllables, then emphasizing the syllable should result in faster reaction times than when the word is presented as a whole. They observed that presenting the first syllable (for 250 ms) followed by the second resulted in equivalent naming times when compared to the whole word condition and concluded that the syllable is not a functional unit in word naming. Several other studies that have explored the poten-

tial role of syllables in naming by directly comparing monosyllabic and polysyllabic words have yielded inconsistent results. For example, Klapp, Anderson, and Berrian (1973) reported that response latencies in a word-naming task were longer for two-syllable words than for one-syllable words. However, other studies have reported no effect of number of syllables on initiation of word naming (e.g., Forster & Chambers, 1973; Frederiksen & Kroll, 1976).

On the other hand, two recent studies (Meyer & Schriefers, 1991; Tousman & Inhoff, 1992) have reported that the naming of a target word or of a target picture is facilitated by the prior presentation of clearly visible or audible primes that corresponded to the first syllable of the targets. For example, Tousman and Inhoff (1992) reported evidence for the syllable's role in bisyllabic word naming. They showed that the naming latencies of the word GLUCOSE, for example, were faster when preceded by the prior presentation (for 250 ms) of a prime that corresponded to the first syllable (e.g., GLU) compared to the prior presentation of a neutral prime (e.g., —). In Meyer and Schriefers' (1991) picture-word interference study, subjects named bisyllabic picture names while hearing distractor words that shared the first or the second syllable with the picture names or were unrelated to the picture names. Both types of related distractors facilitated picture naming in comparison with unrelated distractors and under certain timing conditions. Distractors sharing the first syllable facilitated naming responses when presented 150 ms before, at, or 150 ms after picture onset, whereas distractors sharing the second syllable facilitated the responses only when presented at or 150 ms after picture onset. These results suggest that polysyllabic words are encoded syllable-by-syllable from beginning to end.

One problem in interpreting the results of the above research using long onset asynchronies is the possible use of predictive strategies by subjects on noticing the relationship between certain prime-target pairs. Since in the present study we are primarily interested in

the highly automatized processes involved in normal word or picture naming, it is essential to avoid any contamination by strategic factors. One means of removing this possibility is to reduce prime visibility drastically through shorter presentation durations and massive forward and backward masking. To this end we use the masked priming technique whose utility has been clearly demonstrated in prior research (see Ferrand et al., 1994).

#### THE PRESENT STUDY

In a seminal study of speech perception, Mehler, Dommergues, Frauenfelder, and Segui (1981) demonstrated that French subjects responded faster in a monitoring task when the target corresponded to the first syllable of the stimulus word than when it corresponded to a longer or a shorter segment than the first syllable. Each target corresponded to a complete syllable in only one of the two words: PA was exactly the first syllable of the word PA.LACE,<sup>1</sup> but less than the first syllable of the word PAL.MIER whereas PAL was exactly the first syllable of PAL.MIER, but more than the first syllable of PA.LACE. Thus the target PA was detected faster in the word PA.LACE than in the word PAL.MIER, whereas the target PAL was detected faster in PAL.MIER than in PA.LACE. These results therefore provide evidence for the syllable as a fundamental unit of speech perception in French, with a prelexical level of stored syllables mediating between the speech input and the mental lexicon. More recently, Wheeldon and Levelt (1995) have used a production variant of the syllable monitoring task of Mehler et al. (1981) in which subjects were instructed to silently generate the translation of a given stimulus word and to monitor their production for a given syllable target. They replicated the standard syllabic effect in that responses to targets were faster when they corresponded to the initial syllable of the generated word than when they did not. According to the authors, these results provide evidence that subjects

base their responses on the generation of a syllabified phonological representation.

In the following experiments, we used the masked priming technique combined with the naming task (see Ferrand et al., 1994) and applied Mehler et al.'s (1981) design to study the possible role of the syllable in word and picture naming. In order to test the validity of the syllable as a unit of naming, we exploited the fact that, in French, words with the same initial phoneme sequence may have different initial syllables. Indeed, although the words BAL.CON and BA.LADE share the first three phonemes /b/, /a/, and //, their syllabic structure differs, such that BAL is exactly the first syllable of BAL.CON, but more than the first syllable of BA.LADE, whereas BA is exactly the first syllable of BA.LADE, but less than the first syllable of BAL.CON. Note that French has a regular syllable structure and clear syllable boundaries (for a specific reference to French phonology, see Kaye & Lowestamm, 1984), with minimal consonantal ambisyllabicity, especially between the first and second syllables of polysyllabic words. For example, for the French word BALADE there is a clear syllable boundary between BA- and -LADE. If we hypothesize that syllables play a central role over and above phoneme units in naming, then we should observe a facilitation when primes and targets share phonemes that constitute a syllable unit as opposed to when primes and targets share phonemes that do not constitute a syllable unit. Using the same type of stimuli, Mehler et al. (1981) found evidence for the syllable's role as a unit of speech perception.

Thus, the purpose of the present research was (1) to find out if the phonological codes that are generated from a masked prime are structured syllabically, and (2) to identify the level(s) of processing (perceptual or articulatory) at which syllabic codes are involved in naming (if they are involved at all). One promising avenue to constrain a future unified model of orthographic and phonological processing is a multilevel, multitask approach discussed in detail by Jacobs and Grainger (1994; see also Grainger & Jacobs, in press; Jacobs,

<sup>1</sup>Throughout the article we denote syllable structure using a period.

1994). This involves using several tasks that are thought to cover different areas of the global word recognition and naming spectrum and to share a certain number of common processes. Thus, for example, it is clear that word and picture naming share an articulatory component, whereas lexical decision and word naming must share some early perceptual components. On the basis of commonalities and differences in the patterns of effects observed in the different tasks we can therefore limit the range of possible underlying mechanisms.

In the following experiments, the subject's task was to name words, nonwords or pictures as quickly as possible or to rapidly classify letter strings as words or nonwords. The experimental conditions differed in terms of the type of relationship between the prime and the target. In Experiment 1, bi- and trisyllabic target words were preceded by visual sequences that corresponded (e.g., bal%-%-BAL.CON, ba%-%-%-BA.LADE) or did not correspond (e.g., ba%-%-%-BAL.CON, bal%-%-%-BA.LADE) to the first syllable. Experiment 2 tests the syllable's role using nonwords as targets. Experiment 3 tests the syllable's role in the lexical decision task using words and nonwords as targets. Finally, in Experiment 4, target pictures were preceded by primes that corresponded or did not correspond to the written transcript of the first syllable of the picture's name.

#### EXPERIMENT 1: BISYLLABIC AND TRISYLLABIC WORDS

##### Method

*Subjects.* Forty psychology students at René Descartes University, Paris, France, served as subjects for course credit, 20 in Experiment 1A (bisyllabic words) and 20 in Experiment 1B (trisyllabic words). All were native speakers of French, with normal or corrected-to-normal vision.

*Stimuli and design.* In Experiment 1A, 18 pairs of monomorphemic bisyllabic French words (six letters long) of similar printed frequency sharing the same initial three pho-

nemes (CVC) were selected such that these phonemes made up the first syllable for one member of the pair and the first two (CV) phonemes formed the first syllable of the second member of the pair. For instance, in the pair BA.LADE/BAL.CON the first three phonemes (/b/ /a/ /l/) are identical, but the CVC sequence corresponds to the first syllable of the word BAL.CON and the CV sequence corresponds to the first syllable of the word BA.LADE. The average frequency was 96 occurrences per million for the CVC word targets (ranging from a minimum of 1 to a maximum of 982) and 77 occurrences per million for the CV word targets (ranging from a minimum of 1 to a maximum of 768; *Trésor de la langue française*, 1971). For each of the 18 pairs the initial consonant was either a voiced or a voiceless stop and the second was a liquid (either /l/ or /r/). For each target word, two types of primes were selected: (1) primes that correspond to the first syllable (e.g., bal%-%-%-BAL.CON and ba%-%-%-BA.LADE), or (2) primes that do not correspond to the first syllable (e.g., ba%-%-%-BAL.CON and bal%-%-%-BA.LADE). In Experiment 1B, 16 pairs of monomorphemic trisyllabic French words (eight letters long) were selected by applying the same constraints as those used for the bisyllabic words in Experiment 1A. For example, in the pair PA.RA.SITE/PAR.TI.SAN the first three phonemes (/p/ /a/ /r/) are identical but the CVC sequence corresponds to the first syllable of the word PAR.TI.SAN, whereas the CV sequence is the first syllable of the word PA.RA.SITE. The prime-target pairings were constructed in the same way as those in Experiment 1A. The average frequency was 6 occurrences per million for the CVC word targets (ranging from a minimum of 0 to a maximum of 16) and 5 occurrences per million for the CV word targets (ranging from a minimum of 0 to a maximum of 20; *Trésor de la langue française*, 1971). For both Experiments 1A and 1B, each target word was presented twice to a given subject, paired with one of the two alternative primes in the first half of the experiment and with the other possible prime in the second

half. The two categories of word targets (CVC and CV words) represent the factor Type of Target, whereas the two categories of prime stimuli (CVC% and CV% primes) represent the factor Type of Prime. The two factors were crossed in a  $2 \times 2$  factorial design. Two groups of subjects were used to counterbalance the presentation order of a given word target and its two corresponding primes. Thus, two orders of presentation were used and each subject received all the priming conditions and saw the target words twice in either of the two orders.

*Procedure.* Stimuli were presented in isolation on the center of the display screen of a personal computer with a 70-Hz refresh rate. The items appeared on the screen as white characters on a dark background. Each character (in uppercase) covered approximately  $0.38^\circ$  of visual angle from a viewing distance of 60 cm, so the target words subtended about  $2.28^\circ$  of visual angle. The masked priming procedure with the naming task used in the experiments of Ferrand et al. (1994) was adopted here. Each trial consisted of the following sequence of four stimuli presented on the same screen location. Primes were always completely covered by the mask. First a forward mask consisting of a row of six (or eight) hashmarks (#####) was presented for 500 ms. This was immediately followed by presentation of the prime for 29 ms, followed immediately by a backward mask (#####) for 14 ms, which, finally, was immediately followed by presentation of the target word both (the prime and the target) presented in the same screen location as the masks. The target remained on the screen until the subjects responded. Primes were always presented in lowercase and targets in uppercase. Subjects were asked to fixate the middle of the forward mask. They were also instructed to name as rapidly and as accurately as possible the target word. The existence of a prime was not mentioned. The computer recorded the naming times, measured from target onset to the triggering of the voice key by the subject's response (via a Sennheiser MD211N microphone). The experimenter sat in the same

room as the subject in order to check and note the responses of the subject. The next sequence followed after a 2-s delay. Stimulus presentation was randomized, with a different order for each subject.

### Results

Mean naming latencies and percentage of errors are given in Table 1 for both the bisyllabic and trisyllabic words. Latencies longer than 1000 ms were excluded (less than 1.5 and 2% of the data for bisyllabic and trisyllabic words, respectively). Separate ANOVAs were run for Experiments 1A and 1B with Type of Target (CV or CVC words) and Type of Prime (CV or CVC primes) entered as main factors. *F* values are reported by subjects (*F*<sub>1</sub>) and by items (*F*<sub>2</sub>).

*Experiment 1A: Bisyllabic words.* The main effect of Type of Target was not significant ( $F(1,19) = 3.16$  and  $F_2 < 1$ ) and neither was the main effect of Type of Prime (both  $F_s < 1$ ). On the other hand, the interaction between these two factors was significant ( $F(1,19) = 42.11$ ,  $p < .001$ , and  $F_2(1,17) = 58.36$ ,  $p < .001$ ). The interaction reflects the fact that naming latencies were faster when CVC word targets were preceded by CVC primes than when they were preceded by CV primes and when CV word targets were preceded by CV primes than when they were preceded by CVC primes. An analysis of the error data showed no main or interaction effects (all  $F_s < 1$ ).

*Experiment 1B: Trisyllabic words.* The main effects of Type of Target and Type of Prime were not significant in either analysis (all  $F_s < 1$ ). On the other hand, the interaction between target and prime type was significant ( $F(1,19) = 19.66$ ,  $p < .001$ , and  $F_2(1,15) = 8.33$ ,  $p < .02$ ). As can be seen in Table 1, this interaction illustrates the same pattern of effects as obtained with the bisyllabic words. An analysis of the error data showed no main or interaction effects (all  $F_s < 1$ ).

### Discussion

The main purpose of Experiment 1 was to establish whether briefly presented strings of

TABLE 1  
 MEAN NAMING LATENCIES (ms) AND PERCENTAGE OF ERRORS  
 IN EXPERIMENT 1 (BISYLLABIC AND TRISYLLABIC WORDS)

Bisyllabic word targets	CV word targets (e.g., ba.lade)	CVC word targets (e.g., bal.con)	Mean
CV primes (e.g., ba% % % %)	567 (0.4)	589 (0.7)	578
CVC primes (e.g., bal% % %)	599 (0.6)	558 (0.4)	578.5
Mean	583	573.5	
Trisyllabic word targets	CV word targets (e.g., pa.ra.site)	CVC word targets (e.g., par.ti.san)	Mean
CV primes (e.g., pa% % % % %)	608 (0.8)	626 (1.2)	617
CVC primes (e.g., par% % % % %)	632 (1.0)	604 (0.9)	618
Mean	620	615	

letters activate syllable-sized units involved in the process of word naming. It was observed that naming latencies were faster when the prime stimuli formed the first syllable of the target word than when primes were one letter more or less than the first syllable. These results, obtained both for bisyllabic and for trisyllabic words, indeed suggest that syllable-sized units are rapidly generated from a printed string of letters. One possible locus of this syllabic facilitation effect is at the level of phonological output units that store motor control programs allowing the physical realization of speech sounds. The existence of syllable-sized output units (cf. Levelt & Wheeldon, 1994) within the theoretical framework for word and picture naming sketched by Ferrand et al. (1994) could explain the syllabic priming effects observed in Experiment 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.

An alternative explanation of the results from Experiment 1 would be that initial syllables are access codes for visual word recognition (e.g., Spoehr & Smith, 1973; Taft, 1979, 1987) and that presentation of a prime stimulus that corresponds to a word's initial syllable facilitates the retrieval of the corresponding lexical representation. This would lead to

faster word naming latencies as long as word naming is at least partly dependent on lexical retrieval. According to the access code hypothesis, one should not observe syllabic priming effects in naming tasks using nonword stimuli. According to the output units hypothesis, on the other hand, syllabic effects should also be observed in the speeded naming of nonword stimuli. This is tested in Experiment 2.

## EXPERIMENT 2: NONWORD NAMING

### Method

*Subjects.* Twenty psychology students at René Descartes University, Paris, France, served as subjects for course credit. All were native speakers of French, with normal or corrected-to-normal vision and had not participated in the previous experiment.

*Stimuli and design.* The design was the same as that in Experiment 1A except for the use of nonword rather than word targets. Eighteen pairs of bisyllabic nonwords (six letters long) sharing the first three phonemes (CVC) were created such that these phonemes made up the first syllable for one member of the pair and the first two (CV) phonemes formed the first syllable of the second member of the pair. The nonwords were generated from the French words in Experiment 1A by replacing (after the first three phonemes) a consonant



TABLE 2

MEAN NAMING LATENCIES (ms) AND PERCENTAGE OF ERRORS IN EXPERIMENT 2 (BISYLLABIC NONWORDS)

Bisyllabic nonword targets	CV nonword targets (e.g., ba.lode)	CVC nonword targets (e.g., bal.don)	Mean
CV primes (e.g., ba% % % %)	612 (2.0)	656 (2.2)	634
CVC primes (e.g., bal% % % %)	646 (2.4)	616 (1.9)	631
Mean	629	636	

with another consonant, or a vowel with another vowel, in such a way that only legal syllables in French were used. The prime–target pairings were constructed in the same way as with the word stimuli in Experiment 1A. For example the nonword target BA.LODE was primed with ba% % % % and bal% % % %, and the same was true for the target BAL.DON. As in Experiment 1, two groups of subjects were used to counterbalance the presentation order of a given nonword target and its two corresponding primes. Thus, two orders of presentation were used and each subject received all the priming conditions and saw the target words twice in one of the possible orders.

*Procedure.* Exactly the same procedure as that in Experiment 1, was used, except that subjects were instructed to read aloud nonword stimuli.

### Results

Mean naming latencies and percentage of errors<sup>2</sup> are given in Table 2. Latencies longer than 1000 ms were excluded (less than 3% of the data). An overall ANOVA was performed on the reaction time data with Type of Target (CV and CVC nonwords) and Type of Prime (CV and CVC primes) entered as main factors.

The main effect of Type of Target was not significant ( $F(1,19) = 1.67$  and  $F2(1,17) = 1.95$ ); neither was the main effect of Type of Prime (both  $F_s < 1$ ). On the other hand, the

interaction between target and prime type was significant ( $F1(1,19) = 19.87$ ,  $p < .001$ , and  $F2(1,17) = 6.61$ ,  $p < .02$ ). As in Experiment 1, the interaction reflects the faster naming latencies obtained when CVC nonword targets are preceded by CVC primes than when they are preceded by CV primes and when CV nonword targets are preceded by CV primes than when they are preceded by CVC primes. An analysis of the error data showed no main or interaction effects (all  $F_s < 1$ ).

### Discussion

The fact that we observe a reliable syllable priming effect with nonword targets in Experiment 2 suggests that the syllabic effect obtained with word stimuli in Experiment 1 is not due to the prime stimuli facilitating access to the target word's lexical representation. This would result if access codes for visual word recognition were syllabically structured, and if speeded word naming responses are at least partly determined by lexical retrieval. The fact that nonword targets showed syllabic effects that were very similar to those obtained with word targets suggests that these effects arise in processes other than those required to isolate a specific lexical representation corresponding to the target. One likely locus for these syllabic effects would be the units that are involved in computing an articulatory output in the naming task. As already noted in the introduction, there is accumulating evidence that such codes for output phonology are indeed structured syllabically (e.g., Levelt & Wheeldon, 1994).

In order to provide a further test of the hypothesis that the locus of the syllable priming

<sup>2</sup> All the nonword stimuli had straightforward, unambiguous pronunciations following standard French spelling-to-sound translation rules. Any alternative pronunciation was considered an error.

effect is in output rather than access processes, Experiment 3 uses a lexical decision task, which does not require that the target's phonology be output. If this hypothesis is correct, one should not observe the syllable priming effect for either word or nonword targets in such a task. On the other hand, if the syllable priming effect is affecting lexical access processes, it should be observable in the lexical decision task.

### EXPERIMENT 3: LEXICAL DECISION

#### *Method*

*Subjects.* Twenty psychology students at René Descartes University, Paris, France, served as subjects. All were native speakers of French, with normal or corrected-to-normal vision, and had not participated in the previous experiments.

*Stimuli and design.* The word targets were exactly the same as those used in Experiment 1A. Eighteen new nonword targets (different from those in Experiment 2)<sup>3</sup> were constructed for the purposes of the lexical decision task. These nonwords were created by applying the same constraints as used for the nonwords in Experiment 2. For each nonword target, two types of primes were selected: (1) primes that correspond to the first syllable (e.g., bar%% –BAR.DOL and ba%% –BA.RELE); and (2) primes that do not correspond to the first syllable (e.g., ba%% –BAR.DOL and bar% –BA.RELE).

*Procedure.* Exactly the same procedure as that in Experiment 1 was used except that the task was a lexical decision task. Subjects were instructed to decide as rapidly and as accurately as possible whether the letter string in uppercase that remained on the screen was a French word. Subjects responded "yes" by pressing one of the two response buttons with the forefinger of the preferred hand and "no" by pressing the other response button with the forefinger of the nonpreferred hand.

<sup>3</sup> It was not possible to use the nonwords from Experiment 2 together with the words from Experiment 1A simply because these nonwords were generated from the words in Experiment 1A.

#### *Results*

Mean naming latencies and percentage errors are given in Table 3 for both word and nonword targets. Separate ANOVAs were run for word and nonword targets with Type of Target (CV or CVC targets) and Type of Prime (CV or CVC primes) entered as main factors.

In an analysis of variance conducted on the correct lexical decision latencies and percentage of errors to word targets, no main or interaction effects were significant in either the by-subjects or the by-items analyses (all  $F_s < 1$ ). An analysis of variance on the nonword reaction times and error data also showed no main or interaction effects (all  $F_s < 1$ ).

#### *Discussion*

The same stimuli that produced a syllabic priming effect in the naming task in Experiments 1 and 2 did not produce a similar effect in the lexical decision task in Experiment 3. This null result provides further support for the hypothesis that the syllable priming effect lies in output rather than access processes. However, in order to provide a more convincing positive result in favor of the output phonology hypothesis, Experiment 4 uses pictures of common objects as targets in a naming task. Since picture naming presumably involves the same output phonology as word naming we should observe syllabic effects in this experiment.

### EXPERIMENT 4: PICTURE NAMING

#### *Method*

*Subjects.* Eighteen psychology students at René Descartes University, Paris, France, served as subjects. All were native speakers of French, with normal or corrected-to-normal vision, and had not participated in the previous experiments.

*Stimuli and design.* The design was identical to that used in Experiment 1 except that word targets were replaced by line-drawings of common objects. Ten pairs of monomorphemic bi- and trisyllabic French words corresponding to simple black-on-white drawings

TABLE 3  
 MEAN LEXICAL DECISION LATENCIES (ms) AND PERCENTAGE OF ERRORS  
 IN EXPERIMENT 3 (BISYLLABIC WORD AND NONWORD TARGETS)

Bisyllabic word targets	CV word targets (e.g., ba.lade)	CVC word targets (e.g., bal.con)	Mean
CV primes (e.g., ba%%%%)	587 (5.5)	588 (4.9)	587.5
CVC primes (e.g. bal%%%%)	591 (6.1)	590 (5.3)	590.5
Mean	589	589	
Bisyllabic nonword targets	CV nonword targets (e.g., ba.rele)	CVC nonword targets (e.g., bar.dol)	Mean
CV primes (e.g., ba%%%%)	715 (8.1)	711 (7.5)	713
CVC primes (e.g., bar%%%%)	719 (1.7)	718 (8.0)	718.5
Mean	717	714.5	

of common objects served as target pictures with 20 additional object fillers. The average frequency was 31 occurrences per million for the CVC picture names (ranging from a minimum of 1 to a maximum of 130) and 35 occurrences per million for the CV picture names (ranging from a minimum of 1 to a maximum of 288; *Trésor de la langue française*, 1971). The pictures were selected from a French book of pictures (L'imagerie du Père Castor, 1991) digitized (using a HP-Scan Jet IICx), and edited with PaintBrush. At a viewing distance of 60 cm, the mean angular size of the pictures was 2.5° horizontally and vertically. As in Experiment 1, the pairs of target picture names shared the same initial three phonemes (CVC) and were selected such that these phonemes made up the first syllable for one member of the pair and the first two (CV) phonemes formed the first syllable of the second member of the pair. Thus, in the pair CA.ROTTE/CAR.TABLE (meaning *carrot* and *schoolbag* in English) the initial CVC sequence corresponds to the first syllable of the word CAR.-TABLE, whereas the CV sequence is the first syllable of the word CA.ROTTE. Each picture target was primed by both a CVC and a CV prime with the order of presentation of these priming conditions being counterbalanced across subjects, as in the previous experiments.

*Procedure.* The same procedure as that in

Experiment 1 was used except that word targets were replaced by picture targets that subjects had to name as quickly and as accurately as possible. Before starting the experiment proper, the subjects were given a booklet including all drawings (following Ferrand et al., 1994). Next to each object was printed the word. The subjects were asked to examine all the drawings, to study their names, and to use only those names to refer to the pictures.

### Results

Mean naming latencies and percentage of errors are given in Table 4. Latencies longer than 1500 ms were excluded (less than 3% of the data). An ANOVA was performed on the reaction time data with Type of Target (CV and CVC picture names) and Type of Prime (CV and CVC primes) entered as main factors.

The main effect of Type of Target was not significant ( $F_1 < 1$  and  $F_2 < 1$ ), neither was the main effect of Type of Prime (both  $F_s < 1$ ). On the other hand, the interaction between target and prime type was significant ( $F_1(1,17) = 9.96, p < .01$  and  $F_2(1,9) = 23.02, p < .001$ ). An analysis of the error data showed no main or interaction effects (all  $F_s < 1$ ). As in Experiments 1 and 2, the interaction reflects the faster naming latencies to CVC picture targets when preceded by CVC primes compared to CV primes, and the faster RTs to CV picture targets when they are pre-

TABLE 4

MEAN NAMING LATENCIES (ms) AND PERCENTAGE OF ERRORS IN EXPERIMENT 4 (PICTURES)

Picture targets	CV picture targets (e.g., ca.rotte)	CVC picture targets (e.g., car.table)	Mean
CV primes (e.g., ca% % % % %)	715 (11.5)	750 (13.0)	732.5
CVC primes (e.g., car% % % % %)	755 (12.0)	706 (12.0)	730.5
Mean	735	728	

ceded by CV primes compared to CVC primes.

### Discussion

When a target picture is preceded by a prime that corresponds to the written transcript of the picture name's first syllable, naming latencies were faster when compared to the case in which the prime does not correspond to the first syllable of the picture's name. This observation of syllabic priming with picture targets provides strong evidence that briefly presented letter string primes rapidly activate phonological output units that are structured syllabically. The fact that very similar syllabic priming effects are observed in picture, word, and nonword naming but not in a lexical decision task strongly suggests that they are indeed located at the level of output phonology (articulatory encoding) where presumably the same processes are involved in naming these different types of targets.

### GENERAL DISCUSSION

The results of the present experiments clearly demonstrate that briefly presented masked primes corresponding to the initial syllable of word, nonword, or picture targets facilitate the naming of these targets in French. On the other hand, these same prime stimuli did not affect performance to word and nonword targets in a lexical decision task. All these results converge to suggest that the syllabic priming effects observed in such extreme presentation conditions is located at the level of output phonology. An alternative explanation in terms of syllabically structured access codes in visual word recognition (Spoehr &

Smith, 1973; Taft, 1979, 1987) fails to account for the absence of such effects in the lexical decision task and cannot explain the presence of these effects in nonword naming. In all cases in which a syllabic effect was observed, subjects had to produce an articulatory output thus implying that it is the units involved in generating such an articulatory output that are structured syllabically.

Within the theoretical framework for word and picture naming presented by Ferrand et al. (1994), this rapid activation of output phonology arises via the direct connection between orthographic input units (i.e., letter or letter cluster codes) and output phonology. When a prime stimulus corresponds to the initial syllable of the following target, then the appropriate initial syllable unit will be activated for articulatory output, thus allowing a faster generation of the target's articulatory output compared to when the prime does not correspond to the target's initial syllable. The fact that we did not observe syllabic priming effects in the lexical decision task does not imply, of course, that this task is insensitive to phonological priming. With monosyllabic word targets, Ferrand and Grainger (1992, 1993, 1994) have consistently observed phonological priming effects (primes were pseudohomophones of the target) in the lexical decision task. However, while orthographic priming effects appeared with prime exposures similar to those used in the present experiments, phonological priming effects required longer prime exposures (see Ferrand & Grainger, 1993). Therefore, it is possible that syllabic priming effects would appear in the lexical decision task with longer prime expo-

sure durations, if such sublexical input phonology is structured syllabically. The point, however, in demonstrating that there is no syllabic effect in the lexical decision task when using exactly the same presentation conditions that allowed the effects to emerge in word naming, is to rule out an access code account of the word naming results.

Indeed, the recent work of Carreiras, Alvarez, and De Vega (1993) does suggest that syllable-sized units play a role in visual word recognition. These authors found that Spanish words containing syllables that occur frequently in Spanish were harder to recognize than words containing low frequency syllables. Since this inhibitory syllable frequency effect was obtained in both the lexical decision and word naming tasks, it is likely to reflect lexical access processes that are sensitive to syllable-sized units. According to Carreiras et al., all words that have one syllable in common with the target word will be partially activated upon target presentation and subsequently interfere in the recognition process. Within the theoretical framework described by Ferrand et al. (1994), the syllable-sized units responsible for the inhibitory syllable frequency effect would be located at the level of sublexical input phonology. Upon presentation of a written word, these syllabic representations would receive activation from sublexical orthographic units and send on activation to whole-word representations, thus influencing the process of visual word recognition. If sublexical input phonology is syllabically organized, then one is led to predict that syllabic priming effects should appear in the lexical decision and perceptual identification tasks when using longer prime exposures than in the present experiments. This is clearly an important point for further investigation.

#### *Relation to Speech Production*

The syllable priming effects reported in the present study support the hypothesis that syllable units are functional units in the production of French. Such units have already

been proposed in models such as those of Crompton (1981), Dell (1988), and Levelt (1989, 1992). According to Crompton (1981, p. 663), “. . . the construction of articulatory programs involves the accessing of a library of articulatory routines. These routines correspond to syllables, while their addresses in the library are expressed in a form analogous to classical phonemic representation. The instructions employed in accessing the library involve the transfer of phonological information from the lexicon. This transfer takes place syllable-constituent by syllable-constituent.” This model, therefore, clearly predicts faster reaction times when one of the syllables of a target word (or nonword) is preactivated by the prime. Levelt’s (1989) production model also predicts a priming effect for syllable units. According to Levelt (1989, 1992, 1993, 1994), each speaker possesses a *syllabary* (i.e., a library of syllable-sized motor programs) that stores motor programs corresponding to all the syllables of the language. Phonological representations consist of phonemes, but these phonemes will be used to address the syllabary, and producing a word involves retrieving/assembling one or more of these articulatory syllables. Access to the syllabary is governed by the same principles that govern access to the lexicon, that is, a syllable would be all the more easily accessed the more frequently it is used.

A count of the number of different syllables in French yielded 6000 from a sample of over 200,000 word types (Cerf, Danon, Derouault, El Beze, & Merialdo, 1989). This number is very close to the number of syllables in English, about 6600 (Levelt, 1989). Of course, not all possible syllables are stored in this dictionary of syllables. If this syllabary contained not only actual but also any potential syllable in a language such as French, we would end up with about 33,600 possible syllables (count based on the computerized French database BDLEX: Cerf et al., 1989; Dupoux, 1993). This number of all possible syllables in the French language seems excessive in comparison with the size

of the mental lexicon. In contrast, the number of actual syllables is relatively small. However, speakers must be able to produce new but well-formed kinds of syllables: Levelt (1989) suggests that they can produce these new syllables by analogy. This is in fact presumably the way they acquired their syllable repertoire to start with. Another argument in favor of a mental syllabary is that most syllables are highly overused units of articulation: it would be wasteful to fully program them time and again (Levelt, 1993).

Levelt and Wheeldon (1994) tested this syllabary hypothesis on the basis of its prediction of a syllable frequency effect. Subjects had to produce bisyllabic words in response to abstract visual patterns they had learned to associate with these words. The authors used four types of words: low-frequency words with low-frequency syllables, low-frequency words with high-frequency syllables, high-frequency words with low-frequency syllables, and high-frequency words with high-frequency syllables. They observed both a word and a syllable frequency effect, the two effects being independent, suggesting that the mental lexicon and the mental syllabary are indeed independent stores.

More directly related to the present study is the recent work of Wheeldon and Levelt (1995). As noted in the introduction, these authors replicated the syllable monitoring effect first observed in speech perception by Mehler et al. (1981). In their Experiment 2, Wheeldon and Levelt (1995) used a translation task where Dutch subjects (who had a good knowledge of English) had to generate the Dutch translation of an auditorily presented English word and to monitor their production for a prespecified target string. The results of this experiment show that subjects were much faster in monitoring for a target string when it matched the first syllable of the produced word than when it did not, regardless of the length of the target string. Wheeldon and Levelt concluded that subjects based their responses on the output from the process that assigns phonemes to

a syllabified prosodic frame. Our results extend this finding showing that the syllabic effect is also observed in a standard word and picture naming task as a function of the initial syllable match between a masked letter string prime and the to be named target.

#### *Relation to Spoken and Visual Word Recognition*

Research in languages with clear syllable boundaries such as French, Spanish, Catalan, or Portuguese shows positive evidence for the listener's sensitivity to the syllable in speech perception, whereas the results for English are less clear (see Segui et al., 1990, and Cutler, 1993, for reviews). These results suggest that the syllable is probably not a universal unit of processing. Instead, Cutler (1993) and Otake, Hatano, Cutler, and Mehler (1993) suggest that language rhythm determines the segmentation units most natural to native listeners. Thus, French, Spanish, Portuguese, and Catalan have syllabic rhythm, and French, Spanish, Portuguese, and Catalan listeners use the syllable in segmentation, while English has stress rhythm, and segmentation by English listeners is based on stress. In the case of Japanese which has a mora rhythm, Japanese listeners use the mora in segmentation.

The results obtained in the present experiments mirror those obtained in speech perception (at least in French), suggesting a similarity between units involved in speech production and speech perception in French. Similarly, the mora (rather than the syllable) plays an important role in the recognition (Otake et al., 1993) and production (Kubozono, 1989) of Japanese. It would therefore appear that spoken word recognition and production involve the same basic units. Since research on speech perception has shown that ambisyllabicity undermines the role of syllabic units in English, it will be interesting to examine whether this is also the case with speech production. We are currently examining this in a series of experiments conducted in English and in Spanish.

One other interesting question for future

research concerns the extent to which the phonological codes generated from a printed word are similar to those involved in understanding a spoken word. Since syllabic units appear to be involved in the recognition of spoken French (e.g., Mehler et al., 1981), then if visual word recognition involves the same sublexical phonology as spoken word recognition, one should also observe such syllabic effects in the recognition of printed French words. Some recent experiments suggest that this is indeed the case. Colé (1993) ran a visual analog of the Mehler et al. study where subjects had to say whether a given stimulus word (e.g., PA.LACE) began with a target letter sequence (e.g., PAL) presented visually just before. She found a significant syllable monitoring effect in good beginning readers and also in adult readers. Nevertheless, one could argue that subjects use some form of articulatory code to perform this syllable detection task and that such results do not necessarily imply that sublexical input phonology is organized syllabically. Such a conclusion is supported by the present demonstration of an extremely rapid generation of syllabically structured codes for output phonology in the masked priming paradigm. In these extreme conditions, no syllabic priming was observed in the lexical decision task, thus reinforcing our conclusions that results obtained with the naming task are indeed located in the coding required to generate an articulatory output. Thus, as noted above, it will be important to examine in future research whether syllabic priming effects are observable in visual word recognition tasks such as lexical decision and perceptual identification with appropriate prime exposures. If sublexical input phonology is structured syllabically then one should observe such effects. Furthermore, with respect to the hypothesis that visual and spoken word recognition share the same sublexical phonological codes, syllabic priming effects should also occur in a cross-modal (masked visual prime–auditory target) priming situation.

Ongoing research is currently examining these important questions.

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