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Phonological Priming Between Monosyllabic Spoken Words

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Phonological priming between 3-phoneme monosyllabic spoken words was examined as a function of the early or late position of the phonological overlap between the words and of prime–target relative frequency. The pairs of words had either the 2 beginning or the 2 final phonemes in common. Four experiments were conducted, each using a different combination of interstimulus interval (ISI; either 20 ms or 500 ms) and task (either lexical decision or shadowing). Facilitation was consistently found between words with final overlap in both tasks and was not affected by either absolute or relative word frequency. The size of the effect decreased as the ISI increased. Significant priming effects were not obtained between words with initial overlap, although an inhibitory trend was found in the shadowing task at the short ISI for the low–high relative frequency condition. It is suggested that the facilitatory effect of final overlap is prelexical.

A major issue in research on spoken word recognition has been that of determining the processes underlying the mapping between the acoustic signal and the entries stored in the mental lexicon. Phonological priming has been used to address this question. The basic idea is that when the overlap between the prime and the target coincides with one of the units whose representation mediates lexical access, activation of such a unit during prime processing may facilitate or inhibit the subsequent processing of the target. The predictions resulting from some leading models of spoken word recognition (the cohort model, the neighborhood activation model [NAM] and TRACE) are described here.

According to the first version of the cohort model (Marslen-Wilson & Welsh, 1978), the initial acoustic–phonetic information from an utterance activates in parallel a cohort of all of the word candidates that are matched from onset with the input. Recognition occurs when a single candidate remains compatible with the incoming sensory information. This version of the cohort model predicts facilitation of a target item by a prime belonging to the target cohort (i.e., sharing common initial phonemes). Facilitation is due both to residual activation of the units involved (according to Marslen-Wilson & Welsh, 1978, p. 56, the eliminated candidates "may remain activated for a short period thereafter") and to the absence of inhibition among them. However, the latest version of the cohort model (Marslen-Wilson, 1987, 1990) incorporates a process of discrimination among lexical neighbors. Indeed, in this new version, the degree of activation of the cohort members depends both on their goodness of fit with the incoming sensory information and on their frequency of occurrence, the latter being coded in the resting level of the lexical units. Because recognition occurs when the level of activation of a lexical unit is greater than that of its neighbors by some criterion value, phonological priming can be modulated by the prime–target relative frequency. Nevertheless, the likelihood of obtaining a priming effect seems rather low in light of the results of a study (Marslen-Wilson, 1990) dealing with the role of competitor frequency in the recognition of isolated spoken words. According to Marslen-Wilson (1990, p. 158), the competitor effect is "a transient effect that has dissipated by the time the end of the word is reached." Because priming can be observed only if activation outlasts target presentation by a sufficient period, a consequence of the rapid temporal decay of activation in studies using spoken items that are distributed over time is that any priming effect will most probably have dissipated by the end of the target. However, most of the experiments conducted on phonological priming (see later discussion) have been based on the first version of the cohort theory, which postulated residual activation without competition, so it has been assumed that a prime sharing the initial phonemes with the target will facilitate target recognition.

Although, like the cohort model, NAM (proposed by Luce, 1986; see also Luce, Pisoni, & Goldinger, 1990) is

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based on bottom-up activation, its predictions are different. On the one hand, NAM assumes that frequency is not coded in the resting level of word units but in higher level lexical information, which biases word decision units by means of a neighborhood probability rule. According to this rule, the probability of identifying a word depends directly on its frequency and inversely on the density and frequency of its neighbors. NAM thus predicts inhibition between partially overlapping lexical items because increasing the activation level of a word neighbor by presentation of a phonologically overlapping prime should lower the probability of identifying the target word. On the other hand, contrary to the cohort model's emphasis on word onsets, NAM does not take positional alignment into account in computing the neighborhood. Instead, having been developed for short words, NAM defines the neighborhood in terms of the "*n*-count" notion (Coltheart, Davelaar, Jonasson, & Besner, 1977), whereby neighbors have the same number of phonemes. Phonological priming is thus expected whatever the position of the phonemic overlap.

The interactive-activation model (TRACE) proposed by McClelland and Elman (1986) fails to account for phonological priming. The reason for this deficiency is that, to overcome the problem of segmenting a continuous speech stream into words, TRACE assumes multiple copies of the complete lexical network at each point in time at which a word might begin. Thus, if a word is presented two times consecutively, these two presentations activate separate lexical units.

In summary, the models considered make different predictions regarding phonological priming. The problem is that phonological priming effects do not really help in distinguishing among the models. First, as the subsequent review of the studies shows, the results obtained so far are partly inconsistent. Second, evidence that the reported effects, or some of them, concern lexical representations rather than earlier prelexical codes is scarce. At this stage, a detailed review of the literature is necessary. For clarity, the studies are presented separately according to the location of phonological overlap they have examined (initial, final, or both). They are summarized in Appendix A.

Initial Phonological Overlap

Using the lexical decision task and interstimulus intervals (ISIs) between prime and target of 50 ms or 500 ms, Slowiaczek and Pisoni (1986) did not find any priming effect, either facilitatory or inhibitory, of four-phoneme monosyllabic primes on target words overlapping from onset. However, using similar materials and a task consisting of identifying target words masked with white noise (the prime being in the clear), Slowiaczek, Nusbaum, and Pisoni (1987) found facilitatory effects of phonological overlap by at least two phonemes from onset. Facilitatory effects were also observed with pseudoword primes sharing three phonemes from onset.

Using both lexical decision and shadowing, Radeau, Morais, and Dewier (1989) examined the effects of initial overlap between disyllabic primes and targets separated by ISIs varying from 20 ms to 400 ms as a function of prime duration. Stimulus onset asynchronies (SOAs), rather than ISIs, were fixed. In the lexical decision task, results opposite in direction were found in two experiments that differed in both the lexical status of the prime and the presence or absence of trials in which the prime and target were identical (repetition trials). When repetition trials were included, overlap of two phonemes (corresponding to the first syllable) gave rise to an interference effect for word targets but not for pseudoword targets. When repetition trials were excluded (to avoid effects resulting from participants anticipating repetitions) and pseudoword primes were used, the interference effect was observed for pseudoword targets, and a minor facilitatory effect was found for word targets that shared at least the first three phonemes with their prime. In the shadowing task, the results obtained in the context of repetition trials followed the same pattern as in the lexical decision task. However, without repetitions, the shadowing condition no longer gave rise to any interference or facilitation. This led us to postulate that a postlexical congruency checking mechanism was responsible for the effects observed with the lexical decision task.

In an attempt to distinguish phonetic and phonological priming, Goldinger, Luce, Pisoni, and Marcario (1992) used both identification in noise and lexical decision. In the first task, they obtained facilitation with monosyllabic items composed of three phonemes when primes and targets overlapped from the onset by one phoneme. The effect, however, was strongly reduced when the proportion of related trials was 10% rather than 50%, which suggests the presence of a response bias. In the lexical decision task, the facilitatory effect of first phoneme overlap was observed only for targets presented in white noise. There was no effect at all at either ISI when the target was in the clear. However, with an ISI of 50 ms, reducing the proportion of related trials from 50% to 10% changed the direction of the effect from facilitation to inhibition. This led Goldinger et al. (1992) to conclude that the facilitatory effect of initial overlap in phonological priming was caused by a response bias, as Radeau et al. (1989) had previously suggested.

Slowiaczek and Hamburger (1993) also recently proposed a strategic account of the effect of first phoneme overlap in light of the results of a set of experiments they had performed previously (Slowiaczek & Hamburger, 1992). In both studies, the materials consisted of pairs of monosyllabic words sharing one, two, or three phonemes from onset, and the shadowing task was used. The facilitatory effect of initial phoneme overlap previously reported by Slowiaczek and Hamburger (1992) was no longer obtained in conditions using a low proportion of related trials and excluding repetition trials. On the contrary, the interfering effect of three-phoneme overlap obtained formerly was replicated and shown to be unaffected both by the proportion of related trials and by the presence or absence of repetition trials. As shown by Slowiaczek and Hamburger (1992), the interference effect was not observed when nonword primes were used. Moreover, for word primes, it still occurred in cross-modal experiments using a visual prime and an auditory target. These results led the authors to situate the interference effect at the lexical level, accounting for interference in terms of a model close to Colombo's (1986) connectionist model for printed word processing, which assumes that competition occurs between lexical neighbors.

Final Phonological Overlap

Research dealing with the role of final overlap has produced a less diverse pattern of results. With identification in noise (the prime being in the clear), Slowiaczek et al. (1987) found facilitatory effects for overlap of at least the last two or three phonemes of monosyllabic consonant–consonant–vowel–consonant or consonant–vowel–consonant–consonant items.

Investigating the representation of morphological structure, Emmorey (1989) conducted a set of lexical decision experiments using pairs of disyllabic words overlapping from the end. When words with a weak–strong syllabic stress pattern were used, overlap of the final syllable gave rise to a facilitatory effect for prefixed words sharing a root morpheme but to no effect for words that were only phonologically related. By contrast, words with a strong–weak syllabic stress pattern (more frequent in English than the weak–strong pattern) led to large facilitatory effects for primes and targets sharing a last (unstressed) syllable, and the amount of facilitation was not affected by the morphemic status of this syllable. However, sharing of only the rime (vowel and following consonants), even though it constituted an inflectional suffix, did not result in any effect. Recently, using monosyllabic words as prime and target, Burton, Jongman, and Sereno (1993) observed facilitation for rime overlap with both the lexical decision task and the shadowing task.

Comparing Initial and Final Phonological Overlap

Two studies that concerned the role of overlap location came to our attention after the present set of experiments had been run. One of them (Burton, 1992) compared first and second syllable overlap between disyllabic primes and targets using both lexical decision and shadowing. Both tasks yielded facilitation for second syllable overlap and no effect for initial syllable overlap. Facilitation was still observed for rime overlap in the lexical decision task, a result contradictory with the lack of effect reported by Emmorey (1989) for suffix overlap.

The other study, conducted by Corina (1992), used the lexical decision task. First syllable overlap in disyllabic items led to facilitation, a result not reported in either of the studies in which it was sought (Burton, 1992; Radeau et al., 1989). In monosyllabic items, overlap of the initial segments elicited facilitation in items with a short vowel but produced no effect at all in items with a long vowel. Regarding final overlap, the results were consistent with those of the other studies: Facilitation was found for second syllable overlap in disyllabic items and for rime overlap in monosyllabic items.

The foregoing review reveals a rather untidy set of results. Whereas effects going in different directions or, more often, no effect at all have been reported in the case of initial overlap, the effect of final phonological overlap has been more often a facilitatory one (at least, inhibition has not been reported). Thus, the location of phonological overlap may be important. At the theoretical level, as already seen, the predictions of the cohort model and NAM differ regarding overlap position. Neither of these models can account for the main trends of the phonological priming results.

There is, however, an explanation of these results that would relieve the models from any obligation to account for them. The phonological priming data might reflect the involvement of prelexical representations rather than lexical ones. The study by Slowiaczek and Hamburger (1992) was the only one to attempt to distinguish between prelexical and lexical effects using both a manipulation of the lexical nature of the prime and a comparison of unimodal and cross-modal designs. Evidence was obtained for an interference effect at the lexical level. However, the authors considered only initial overlap. It is thus important to compare the effects of initial and final overlap while attempting to verify whether they occur at the level of lexical or prelexical representations.

In the present experiments, we contrasted beginning versus final overlap in monosyllabic primes and targets. Two of the three phonemes of the words were shared by prime and target in each overlap condition. According to the terminology used for analogous relations between written words, we call the prime and target in these conditions *phonological neighbors*. As a means of making the initial overlap and final overlap conditions as similar as possible in other respects (namely energy and type of shared phonemes), the target and the prime shared the vocalic nucleus in both conditions.

To determine whether lexical representations are involved in the phonological priming effects, we manipulated the prime–target relative frequency. The related pairs of items in each overlap condition consisted of a low-frequency and a high-frequency word. In one condition of relative frequency, the low-frequency item was presented as prime and the high-frequency item as target, and this relation was reversed in the other condition.

Word frequency has been shown to affect the speed of spoken word recognition (Connine, Mullennix, Shernoff, & Yelen, 1990; Marslen-Wilson, 1990). However, previous studies on auditory phonological priming have made little if any use of word frequency and, especially, of relative prime–target frequency. To our knowledge, this latter variable was taken into account only in a study run by Goldinger, Luce, and Pisoni (1989), who did not examine phonological priming but phonetic priming. Using identification in noise as the task, the authors computed neighborhood density using confusion matrices for each individual phoneme. Primes and targets were confusable when presented in noise, but they had no phoneme in common (an example of such phonetic neighbors is *veer–bull*). As predicted by NAM, priming with a related word led to less accurate identification of the target, especially when the prime was of lower frequency than the target. As already noted, NAM assumes frequency to affect decision processes. Decisions would be made less quickly for low-frequency words than for high-frequency words, which would allow more time for a low-frequency word to inhibit its neighbors.

The importance of taking frequency relations into account is that using initial and final overlap priming effects to evaluate models of spoken word recognition requires one to demonstrate that these effects arise at the level of lexical representations. The presence of prime–target relative frequency effects would provide evidence for the involvement of lexical representations. Consistent with the results of Slowiaczek and Hamburger (1992), an interference effect was expected in the initial overlap condition. This effect seems to involve lexical representations, and therefore it was expected to be modulated by the prime–target frequency relations. In contrast, the facilitation usually obtained for final overlap is difficult to interpret both on the basis of NAM's logic (i.e., a logic of competition between lexical candidates) and on the basis of the cohort model, because the latter can account only for initial overlap effects. However, final overlap facilitation is inconsistent with NAM if and only if the effect involves the activation of lexical representations. The facilitation effect for final overlap might arise from the activation of prelexical codes. If this is the case, then the facilitation effect should not be modulated by prime–target frequency relations.

The present investigation was conducted with two ISIs (20 and 500 ms). If, as is usually accepted, activation of lexical units returns to resting level after word recognition, the short ISI (20 ms) should give rise to greater effects than the long one (500 ms). The research by Goldinger et al. (1989, 1992) described earlier showed that ISI affects phonological and phonetic priming. The motivation for using a long ISI was that it may help to determine the extent to which the effects may be contaminated by strategies. Whereas one cannot rule out the possibility that strategies can be used at a short ISI, it is likely that increasing the ISI provides a better opportunity to engage in such processing. More priming at a short than at a long ISI would thus argue against bias contamination. However, if it is found that the size of the effect does not decrease over the ISI, the possibility of strategic involvement cannot be discarded.

Finally, task is probably also an important factor in auditory phonological priming effects, as Radeau et al. (1989) have suggested. We included two tasks in the present study: lexical decision and shadowing. Lexical decision is often considered to be affected by postlexical processing (Balota & Chumbley, 1984; Jakimik, Cole, & Rudnicky, 1985; Norris, 1986). Shadowing is less dependent on strategies and on conscious decisions than is lexical decision, but it might take place without recognition that the phonological word form corresponds to a word. This does not imply, however, that the participant repeats the word back without accessing the lexicon (and thus without being influenced by lexical factors). Shadowing has been shown to be sensitive to lexical status (Radeau et al., 1989), to neighborhood density (Luce et al., 1990), to spoken word familiarity (Connine et al., 1990), and, recently, to semantic priming (Slowiaczek, 1994). Obtaining similar phonological priming effects with both tasks would constitute an additional argument for the effects being minimally affected by strategies.

Experiments 1 to 4 all included pairs of items with beginning and final phonological overlap presented in a low–high frequency relation in one condition and in the reverse relation in another condition. Experiments 1 and 2 were run with a short ISI, and Experiments 3 and 4 were run with a long one. The lexical decision task was used in Experiments 1 and 3, and the shadowing task was used in the other two.

Experiment 1

Method

Participants. Forty-eight students at the Free University of Brussels participated as volunteers in the experiment as part of an introductory psychology course. Half of them (6 men and 18 women) were tested in the low–high relative frequency condition, and the other half (3 men and 21 women) were tested in the high–low condition. All students were native speakers of French and reported no hearing defects.

Materials. BRULEX, a lexical database for French (Content, Mousty, & Radeau, 1990), was used in selecting items. Critical items, control items, and fillers were included.

Two sets of 16 pairs of nouns, one pair member of high frequency and one of low frequency, served as critical items. The pairs are presented in Appendix B. Each of the items of a pair was used as a prime or as a target depending on the relative frequency condition under study. All of the nouns were monosyllabic, were three phonemes long, and had their uniqueness point after their end. They began with a stop consonant.

One set of critical items consisted of words beginning with the same two phonemes. This set included 12 pairs with a consonant–vowel–consonant (CVC) structure and 4 pairs with a consonant–consonant–vowel (CCV) structure. The other set of items had the same last two phonemes and included 13 pairs with a CVC structure and 3 pairs with a CCV structure. These two sets of pairs are referred to here as the beginning overlap and the final overlap sets. The number of voiced and unvoiced first consonants was almost the same in both frequency conditions. The set with beginning overlap included 6 voiced and 10 unvoiced consonants in each frequency condition. The set with final overlap included 8 voiced and 8 unvoiced consonants for the low-frequency condition and 7 voiced and 9 unvoiced consonants for the high-frequency condition.

In each set, a pair of phonologically overlapping words included a high-frequency word (greater than 1,000 occurrences per 100 million words or greater than three in terms of logarithmic frequency) and a low-frequency one (fewer than 1,000 occurrences per 100 million). In addition, the difference between the logarithmic frequencies of the two words of a pair was greater than one. These logarithmic frequencies were those calculated in BRULEX from the textual frequencies for printed words given in *Trésor de la Langue Française* (Imbs, 1971). In the beginning overlap set, mean logarithmic frequencies were 2.14 (range: 0.90–2.99) for the low-frequency items and 3.84 (range: 3.23–4.65) for the high-frequency items. In the final overlap set, they were 2.23 (range: 1.30–2.98) and 3.60 (range: 2.78–4.54).

A test of subjective frequency was run on the printed form of the words with two groups of 48 students different from those participating in the experiments but fulfilling the same selection criteria. Each group was tested with words of both kinds of frequency but received only one of the words of each pair. The task consisted of classifying each word on a 6-point scale ranging from *unknown* (1) to *very frequent* (6). Mean subjective frequencies were 3.8 (range: 2.1–4.9) and 5.1 (range: 4.3–5.8) for the low- and high-frequency items of the beginning overlap set and 3.4 (range: 1.9–4.6) and 5.1 (range: 4.1–5.5) for the two types of items of the final overlap set. The correlation between these subjective frequencies and the corresponding logarithmic frequencies was significant when calculated both on the 64 critical items (r = .79, $p < .001$) and on the 32 items of low (r = .37, $p < .05$) or high (r = .59, $p < .001$) frequency.

The durations of the critical words were measured. In the beginning overlap set, the mean word lengths were 537 ms (range: 260–820) for high-frequency words and 567 ms (range: 324–740) for low-frequency words. In the other set, they were 610 ms (range: 282–836) for high-frequency words and 598 ms (range: 330–792) for low-frequency words. An analysis of variance (ANOVA) with overlap and frequency as variables did not reveal any significant effect or interaction. However, because the variation in word duration was rather high, an effect could hardly emerge. Reanalyses of the data taking word duration into account are presented in the joint analysis of the experiments.

For each set, 16 control words served as an unrelated prime for both targets of a pair of critical words (see Appendix B). These control words were monosyllabic and three phonemes long, and they had no phoneme in common with the critical items. Their mean logarithmic frequencies were 3.29 (range: 2.19–5.00) in the beginning set and 3.36 (range: 2.04–5.11) in the final set.

Thirty-two pairs of items consisting of a word and a nonword served as fillers, the word being used as prime and the nonword as target. They were also monosyllabic and three phonemes long. The proportion of CVC and CCV pairs was the same as for the experimental pairs. In half of the pairs, the two items involved an overlap of the two first phonemes (e.g., *pâle–pâze* and *dru–dri*); in the other half, they involved an overlap of the two last phonemes (e.g., *mare–sare* and *pré–dré*).

Procedure. The items were recorded by a male native speaker of French in a soundproof room on a Studer A-810 tape recorder with a Neumann U-87 microphone. A Macintosh II FX computer and the Sound Tools editor were used to digitize items at a sampling rate of 32 kHz and with 16-bit analog-to-digital conversion.

The stimuli were transferred to the left channel of a Sony 55ES digital-to-analog converter. They were stored as pairs of corresponding primes and targets with a 4-s SOA between the primes of two consecutive pairs. There were 20 ms of silence between the offset of the prime and the onset of the target of each pair. A square wave click starting 20 ms before the onset of each target was stored on the right channel of the digital-to-analog converter.

Presentation of the items and collection of data were controlled by an Apple IIe computer connected to the digital-to-analog converter. The stimuli were presented to the student at a comfortable level through a pair of Beyer DT-202 headphones connected to the left channel of the digital-to-analog converter. The click, stored on the other channel and inaudible to the student, triggered a voice key connected to a clock card (Apple Clock Mountain Hardware).

For each relative frequency condition, two lists of items were constructed in which the two types of overlap occurred the same number of times and an item was presented only once. Each list included eight related trials, eight control trials (corresponding to each of the overlapping items), and 32 pairs of fillers. The same fillers were used in both lists and in both conditions of frequency relation. The order of presentation of the stimuli was determined randomly with the restriction that a particular kind of trial (beginning vs. final overlap, related vs. control, or critical vs. filler) did not occur more than three times consecutively. The two lists were heard by different subgroups of 12 students each.

The students participated individually in a quiet room. They were told that the first item of each pair would always be a word but that the second item could be a word or a pseudoword. Their task was to respond to the second item when it was a word. No response was required to nonwords. The students were asked to press a key to target words with their preferred hand as quickly as possible and without making errors. The response key was interfaced to the computer via the game connector.

The experimental items were presented in two blocks of trials in balanced order. Students completed a block of 20 practice trials with equivalent material at the beginning of the session.

Results and Discussion

Reaction times (RTs) were calculated from target onset to response onset. RTs longer than 1,500 ms or shorter than 150 ms and incorrect responses were discarded from the analyses.

Mean RTs and error rates are presented in Table 1. The main result was that strong facilitatory priming effects occurred between words with final phonological overlap but not between those with beginning overlap.

Mean RTs per student and per item were analyzed in ANOVAs with overlap (beginning vs. final), prime type (related vs. control), and frequency (high–low vs. low–high) as variables. The effect of prime type was significant, $F_1(1, 46) = 30.25$, $p < .001$, $MSE = 3{,}662.0$; $F_2(1, 60) = 12.41$, $p < .001$, $MSE = 7{,}428.9$. Control trials were responded to 49 ms slower than related trials. Prime type and overlap interacted significantly, $F_1(1, 46) = 23.11$, $p < .001$, $MSE = 3{,}411.0$; $F_2(1, 60) = 6.81$, $p < .025$, $MSE = 21{,}794.2$. This interaction was due to RTs being significantly faster (89 ms) in related than in control trials in the final overlap condition, $F_1(1, 46) = 65.82$, $p < .001$, $MSE = 2{,}859.6$; $F_2(1, 30) = 10.86$, $p < .001$, $MSE = 139{,}689.1$, but not in the beginning overlap condition (8 ms; both Fs < 1). The effect of frequency was also significant, $F_1(1, 46) = 59.56$, $p < .001$, $MSE = 24{,}133.5$; $F_2(1, 60) = 42.04$, $p < .001$, $MSE = 21{,}794.2$. On average, high-frequency words were responded to 173 ms faster than low-frequency ones. The interaction between overlap and frequency was significant by student, $F_1(1, 46) = 11.87$, $p < .001$, $MSE = 4{,}341.9$, but not by item ($F_2 < 1$). No other variable or interaction was significant in the RT analyses.

ANOVAs on error rates yielded significant effects of frequency, $F_1(1, 46) = 59.92$, $p < .001$, $MSE = 1.9$; $F_2(1, 60) = 14.53$, $p < .001$, $MSE = 10.84$. Error rates were higher for the high–low than for the low–high frequency relation. Moreover, there was a tendency for the number of errors to be greater in the beginning than in the final overlap condition, especially for the high–low frequency relation. However, the effect of overlap, $F_1(1, 46) = 5.43$, $p < .025$, $MSE = 0.75$ ($F_2 < 1$), and the interaction between overlap and frequency, $F_1(1, 46) = 11.08$, $p < .001$, $MSE = 0.75$ ($F_2 < 1$), were both significant only by student. The high error rates associated with the low-frequency targets may have been due to the use of short monosyllabic items, which are more difficult to recognize than longer words. Using excerpts from fluent speech, both Grosjean (1985) and Bard, Shillcock, and Altmann (1988) found that recognition at or before offset occurred more often for multisyllabic than for monosyllabic words.

It may be argued that large ANOVAs taking frequency into account washed out the small priming effects occurring in the beginning overlap condition. Separate ANOVAs were thus performed on the data of the two relative frequency conditions with type of prime (two levels) and overlap (two levels) as variables. In the present experiment and in the next three, we restrict description of the statistical results to the interaction between the two variables, reporting only the F values when they are significant by student, item, or both. In the present experiment, the interaction was not significant.

Overlap of the last two phonemes of a three-phoneme word thus led to a strong facilitatory effect. By contrast, overlap of the first two phonemes did not give rise to any effect. Conversely, whereas high-frequency words were recognized faster and more accurately than low-frequency words, the frequency relation between prime and target had no effect on the amount of priming. The aim of the next experiment was to assess the generality of the present results using the shadowing task.

Experiment 2

Method

Participants. Forty-eight students, selected according to the same criteria as in Experiment 1, participated in Experiment 2; half (2 men and 22 women) were assigned to the low–high relative frequency condition, and half (7 men and 17 women) were assigned to the other relative frequency condition.

Materials and procedure. Experiment 2 differed from Experiment 1 in that it used the shadowing task. The students were asked to repeat each target as quickly and accurately as possible. The responses were detected via a voice key. Apart from the task, the materials and procedure were the same as in Experiment 1.

Results and Discussion

The data were analyzed according to the same criteria as those of Experiment 1. A response was considered incorrect when it deviated by at least one phoneme from the presented item.

The results (see Table 2) were similar in pattern to those of the lexical decision task. Only the final overlap condition gave rise to facilitation. In the beginning overlap condition, there was a tendency for RTs to be slower in related than in control trials. The ANOVAs run on RTs showed related trials being responded to significantly faster (22 ms) than control trials, $F_1(1, 46) = 12.55, p < .001, MSE = 1{,}875.5$; $F_2(1, 60) = 4.17, p < .05, MSE = 4{,}243.4$. The effect of overlap (RTs were 28 ms faster in the beginning than in the final overlap condition) was significant by student, $F_1(1, 46) = 18.80, p < .001, MSE = 1{,}989.9$, but not by item ($F_2 < 1$). The Prime Type × Overlap interaction was significant, $F_1(1, 46) = 50.79, p < .001, MSE = 1{,}583.80$; $F_2(1, 60) = 9.91, p < .005, MSE = 4{,}243.4$. As in Experiment 1, prime type was significant in the final overlap condition (63 ms), $F_1(1, 46) = 87.37, p < .001, MSE = 1{,}075.2$; $F_2(1, 30) = 8.11, p < .01, MSE = 7{,}050.9$, but not in the beginning overlap condition (−18 ms), $F_1(1, 46) = 3.42, MSE = 2{,}344.1$; $F_2(1, 30) = 1.61, MSE = 1{,}435.9$. The effect of frequency (58 ms, on average) was significant, $F_1(1, 46) = 5.92, p < .025, MSE = 26{,}760.8$; $F_2(1, 60) = 6.55, p < .025, MSE = 108{,}519.9$, and did not significantly interact with any other variable.

On errors, a significant effect of prime type was observed in the analysis by student, $F_1(1, 46) = 4.63, p < .05, MSE = 0.2$, but not in the analysis by item ($F_2 < 1$). The effect of frequency, with high-frequency targets unexpectedly associated with higher error rates, was significant in both analyses, $F_1(1, 46) = 5.51, p < .025, MSE = 0.4$;

Table 1
Mean Reaction Times (in Milliseconds) and Error Rates (%) in the Lexical Decision Task of Experiment 1

	Overlap position					
	Beginning			Final		
	Prime type			Prime type		
Prime–target frequency	Related	Control	Difference	Related	Control	Difference
High–low						
Reaction time	891	915	24	849	925	76
Error rate	31.2	33.3	2.1	21.3	25.5	4.2
Low–high						
Reaction time	701	692	−9	696	798	102
Error rate	7.8	7.8	0.0	9.9	8.9	−1
Difference						
Reaction time	190	223		153	127	
Error rate	23.4	25.5		11.4	16.6	

Note. The interstimulus interval was 20 ms.

Table 2
Mean Reaction Times (in Milliseconds) and Error Rates (%) in the Shadowing Task of Experiment 2

Prime–target frequency	Overlap position: Beginning, Prime type: Related	Control	Difference	Final, Prime type: Related	Control	Difference
High–low						
Reaction time	793	780	−13	775	830	55
Error rate	3.6	3.6	0.0	1.0	2.6	1.6
Low–high						
Reaction time	728	705	−23	722	792	70
Error rate	3.1	8.3	5.2	4.7	5.2	.5
Difference						
Reaction time	65	75		53	38	
Error rate	0.5	−4.7		−3.7	−2.6	

Note. The interstimulus interval was 20 ms.

$F_2(1, 60) = 4.18, p < .05, MSE = 0.7$. There was no other significant variable or interaction.

On the whole, the results followed the same pattern as those of Experiment 1. Facilitation was found in the final overlap condition. In the beginning overlap condition, however, there was a tendency toward inhibition in both frequency conditions. An ANOVA performed on the data of the low–high frequency condition gave rise to a significant interaction between type of prime and overlap, $F_1(1, 23) = 45.07, p < .001, MSE = 1{,}158.6$; $F_2(1, 30) = 4.03, p = .05, MSE = 993.6$. The inhibition effect (−23 ms), however, was significant by student, $F_1(1, 23) = 6.48, p < .025, MSE = 993.6$, but not by item, $F_2(1, 15) = 2.53, MSE = 1{,}262.7$. In the high–low frequency condition, in which the inhibition reached only −13 ms, the interaction was not significant.

The finding of a small inhibition effect in this experiment, although significant only by student and in one of the two frequency conditions (the low–high condition), deserves special consideration. Indeed, as noted in the introduction, Slowiaczek and Hamburger (1992, 1993), also using the shadowing task, reported an analogous result for an initial overlap of three phonemes. In these studies, in which relative prime–target frequency was not manipulated, the effect reached −16 ms (Slowiaczek & Hamburger, 1992, Experiment 2A) and −18 ms (Slowiaczek & Hamburger, 1993). The size of the inhibition effect was thus about the same as in the present experiment, in which it reached −18 ms, on average, for the two frequency conditions. The present inhibition effect observed in the low–high frequency condition may have failed to reach significance in the item analysis because of the small number of items tested. Whereas the effect reported by Slowiaczek and Hamburger (1992) was based on 100 pairs of words, the present one was based on 16 pairs of words.

The following two experiments were designed to study the role of ISI by using a longer ISI than in Experiments 1 and 2. If, as generally agreed, strategies such as perceptual or response bias require time (Goldinger et al., 1992; Neely, 1977; Posner & Snyder, 1975), a decay of the priming effect from the short to the longer ISI would be evidence against strategic processing. As was the case for the short ISI, both lexical decision and shadowing were compared. Experiment 3 used the lexical decision task, and Experiment 4 used the shadowing task.

Experiment 3

Method

Participants. The participants were selected according to the same criteria as in the other experiments. Twenty-four students (10 men and 14 women) were tested in the low–high frequency condition, and 24 others (4 men and 20 women) were tested in the high–low condition.

Materials and procedure. The ISI was 500 ms rather than 20 ms. In all other respects, the method was the same as in Experiment 1. In particular, the task was also a version of the lexical decision task in which the student responded only to words.

Results and Discussion

The results are presented in Table 3. Facilitation was again observed in the final overlap condition. The ANOVAs on RTs revealed the prime type effect (19 ms) to be significant in the analysis by student, $F_1(1, 46) = 4.10, p < .05, MSE = 3{,}995.1$, but not in the analysis by item, $F_2(1, 60) = 3.07, MSE = 5{,}545.6$. The Prime Type × Overlap interaction was significant, $F_1(1, 46) = 16.75, p < .001, MSE = 3718.4$; $F_2(1, 60) = 7.85, p < .01, MSE = 5{,}545.6$. This interaction was due to the prime type effect being significant in the final overlap condition, in which it reached 55 ms, $F_1(1, 46) = 20.22, p < .001, MSE = 3{,}525.6$; $F_2(1, 30) = 12.35, p < .005, MSE = 4{,}656.0$, but not in the beginning overlap condition (−18 ms; both Fs < 1). The effect of frequency was significant, $F_1(1, 46) = 47.76, p < .001, MSE = 28{,}967.5$; $F_2(1, 60) = 54.60, p < .001, MSE = 17{,}400.9$. High-frequency words were responded to 170 ms faster than low-frequency ones. The frequency

Table 3
Mean Reaction Times (in Milliseconds) and Error Rates (%) in the Lexical Decision Task of Experiment 3

Prime–target frequency	Overlap position: Beginning, Prime type: Related	Beginning, Prime type: Control	Beginning: Difference	Final, Prime type: Related	Final, Prime type: Control	Final: Difference
High–low						
Reaction time	938	917	−21	851	911	60
Error rate	25.0	28.6	3.6	17.7	20.8	3.1
Low–high						
Reaction time	721	707	−14	731	780	49
Error rate	4.2	4.7	0.5	4.7	7.3	2.6
Difference						
Reaction time	217	210		120	131	
Error rate	21.8	23.9		13	13.5	

Note. The interstimulus interval was 500 ms.

effect reached 214 ms in the beginning overlap condition and 125 ms in the final one. However, the Frequency × Overlap interaction was significant in the analysis by student, $F_1(1, 46) = 27.42$, $p < .001$, $MSE = 3340.9$, but not in the analysis by item, $F_2(1, 60) = 3.15$, $MSE = 17{,}401.0$.

The analyses of error rates revealed a significant effect of frequency, $F_1(1, 46) = 52.56$, $p < .001$, $MSE = 1.9$; $F_2(1, 60) = 16.66$, $p < .001$, $MSE = 8.8$. As in Experiment 1, high-frequency words were responded to more accurately than low-frequency words. The Frequency × Overlap interaction was significant in the analysis by student, $F_1(1, 46) = 9.56$, $p < .005$, $MSE = 0.6$, but not in the analysis by item ($F_2 < 1$). However, the frequency effect was significant in both the beginning, $F_1(1, 46) = 53.73$, $p < .001$, $MSE = 1.4$, and final, $F_1(1, 46) = 26.02$, $p < .001$, $MSE = 1.1$, overlap conditions. No other main effect or interaction was significant in the error analyses. ANOVAs performed on the data of each frequency condition revealed no significant interaction between prime type and overlap.

Experiment 4

Method

Participants. Forty-eight students selected in the same way as in Experiments 1 to 3 served as participants. Half (14 men and 10 women) participated in the low–high frequency condition, and half (8 men and 16 women) participated in the high–low condition.

Materials and procedure. The method was the same as in Experiment 3, except that the shadowing task, in which students were instructed to repeat back each target, was used.

Results and Discussion

The results are presented in Table 4. A small positive priming effect was still observed in the final overlap condition for the two prime–target frequency relations. The effect of prime type was significant, $F_1(1, 46) = 24.50$, $p < .001$, $MSE = 853.6$; $F_2(1, 60) = 8.85$, $p < .005$, $MSE = 1{,}266.2$. Related trials were responded to 21 ms faster than control trials. The beginning overlap condition gave rise to RTs 32 ms faster than those in the final overlap condition. However, overlap was significant in the analysis by student, $F_1(1, 46) = 49.79$, $p < .001$, $MSE = 758.3$, but not in the analysis by item, $F_2(1, 60) = 2.01$, $MSE = 13{,}322.9$. The Prime Type × Overlap interaction was not significant by student, $F_1(1, 46) = 2.13$, $MSE = 2{,}147.4$, but was marginally significant by item, $F_2(1, 60) = 3.40$, $p < .10$, $MSE = 1{,}266.2$. In the item analysis, the priming effect was again significant in the final overlap condition (31 ms), $F_2(1, 30) = 15.24$, $p < .001$, $MSE = 964.2$, but not in the beginning overlap condition (11 ms). There was no effect of frequency in either analysis. The Frequency × Overlap interaction was significant by student only, $F_1(1, 46) = 5.76$, $p < .01$, $MSE = 758.3$. There was a tendency for frequency to have a somewhat stronger influence on RTs in the beginning than in the final overlap condition. However, there was no effect of frequency in either condition.

As in Experiment 2, error rates were somewhat higher for the high-frequency targets than for the low-frequency targets. The analyses of error rates showed this effect to be significant by student only, $F_1(1, 46) = 7.40$, $p < .01$, $MSE = 0.2$. No other variable or interaction was significant in the error analyses. The data of each frequency condition were again submitted to separate ANOVAs, none of which gave rise to an interaction between prime type and overlap.

Joint Analysis of the Experiments

The data of the four experiments were analyzed in an ANOVA with prime type, overlap, frequency, task, and interval as variables (each with two levels). Separate analyses were run on mean RTs and mean error rates by student and by item. For clarity, the main effects or interactions that were significant both by student and by item are considered first.

The effect of prime type, $F_1(1, 184) = 55.45$, $p < .001$, $MSE = 143{,}992.5$; $F_2(1, 60) = 14.55$, $p < .001$, $MSE = 7{,}782.0$, was significant, RTs being 28 ms faster in related

Table 4
Mean Reaction Times (in Milliseconds) and Error Rates (%) in the Shadowing Task of Experiment 4

Prime–target frequency	Overlap position: Beginning — Prime type: Related	Control	Difference	Final — Prime type: Related	Control	Difference
High–low						
Reaction time	906	916	10	914	945	31
Error rate	1.6	1.6	0.0	0.0	0.0	0.0
Low–high						
Reaction time	869	881	12	897	927	30
Error rate	2.1	3.1	1.0	2.6	3.1	0.5
Difference						
Reaction time	37	35		17	18	
Error rate	−0.5	−1.5		−2.6	−3.1	

Note. The interstimulus interval was 500 ms.

trials than in control trials. High-frequency words were responded to faster than low-frequency ones. The effect of frequency was significant, $F_1(1, 184) = 64.37$, $p < .001$, $MSE = 33{,}998.3$; $F_2(1, 60) = 26.93$, $p < .001$, $MSE = 54{,}283.0$. ISI also showed a significant main effect, $F_1(1, 184) = 32.83$, $p < .001$, $MSE = 33{,}998.3$; $F_2(1, 60) = 139.99$, $p < .001$, $MSE = 5{,}116.8$, the long interval giving rise to RTs 76 ms slower than those of the short interval.

The Prime Type × Overlap interaction was significant, $F_1(1, 184) = 71.24$, $p < .001$, $MSE = 2{,}705.2$; $F_2(1, 60) = 15.94$, $p < .001$, $MSE = 7{,}782.8$. RTs were faster in related trials than in control trials (59 ms, on average) in the final overlap condition, $F_1(1, 184) = 153.16$, $p < .001$, $MSE = 2{,}186.9$; $F_2(1, 30) = 21.04$, $p < .001$, $MSE = 11{,}267.3$, but not in the beginning overlap condition (−4 ms). Although initial phoneme overlap had no effect, sharing final phonemes consistently led to facilitation.

There was a significant Task × ISI interaction, $F_1(1, 184) = 23.99$, $p < .001$, $MSE = 33{,}998.3$; $F_2(1, 60) = 314.57$, $p < .001$, $MSE = 1{,}728.9$. The mean RTs were 809 ms and 820 ms in the lexical decision task and 766 ms and 907 ms in the shadowing task for the short and long intervals, respectively. Whereas the ISI had no effect on lexical decision latencies, it affected the shadowing latencies, $F_1(1, 92) = 46.32$, $p < .001$, $MSE = 41{,}446.1$; $F_2(1, 60) = 519.42$, $p < .001$, $MSE = 2{,}414.7$. In addition, with the 20-ms ISI, RTs were faster in the shadowing task than in the lexical decision task, $F_1(1, 92) = 6.94$, $p < .001$, $MSE = 25{,}447.2$; $F_2(1, 60) = 28.81$, $p < .001$, $MSE = 5{,}281.5$; with the 500-ms ISI, they were slower in the shadowing task, $F_1(1, 92) = 17.24$, $p < .001$, $MSE = 42{,}549.4$; $F_2(1, 60) = 96.81$, $p < .001$, $MSE = 4{,}402.7$.

The significant interaction between task and ISI deserves comment. It is possible that the 20-ms interval between the offset of the prime and the onset of the target allowed the student to predict the time of presentation of the target and made him or her more prepared to respond than after the 500-ms interval. Being highly prepared at the right moment may be important when the task requires activating a link already stored, as is the case in shadowing, in which the articulatory program that corresponds to the perceptual representation of a word has to be activated. It may be less important in lexical decision, in which the relation between the stimulus and the response is less direct and must be calculated.

The Frequency × Task interaction was significant, $F_1(1, 184) = 23.60$, $p < .001$, $MSE = 33{,}998.3$; $F_2(1, 60) = 65.67$, $p < .001$, $MSE = 7{,}955.4$. The frequency effect was greater in the lexical decision task (171 ms), $F_1(1, 92) = 106.23$, $p < .001$, $MSE = 26{,}550.5$; $F_2(1, 60) = 53.68$, $p < .001$, $MSE = 34{,}764.3$, than in the shadowing task, in which it was nevertheless significant (42 ms), $F_1(1, 92) = 4.11$, $p < .05$, $MSE = 41{,}446.1$; $F_2(1, 60) = 4.3$, $p < .05$, $MSE = 27{,}474.2$. The finding of a frequency effect on pronunciation latencies is in agreement with the familiarity effect found by Connine et al. (1990) and the frequency effect that Marslen-Wilson (1985) reported (but only on error rates). This frequency effect, together with the effects of lexicality (Radeau et al., 1989), neighborhood density (Luce et al., 1990), and semantic relatedness (Slowiaczek, 1994) observed previously, constitutes good evidence for the view that repeating a spoken word involves lexical access.

Some interactions involving prime type, although significant in only one of the two analyses, deserve special consideration. Although, in the item analysis, prime type did not interact significantly with any variable other than those already reported, both the Prime Type × ISI interaction, $F_1(1, 184) = 4.39$, $p < .05$, $MSE = 2{,}596.6$, and the Prime Type × ISI × Overlap interaction, $F_1(1, 184) = 5.48$, $p < .025$, $MSE = 2{,}705.2$, were significant in the analysis by students. These interactions reflect the fact that whereas there was no effect of prime type with either ISI in the beginning overlap condition, the effect of prime type was greater with the short than with the long interval in the final overlap condition (76 ms vs. 43 ms). In the final overlap condition, the effect of prime type was nevertheless significant with the long ISI, $F_1(1, 92) = 36.15$, $p < .001$, $MSE = 2{,}406.4$, as well as with the short ISI, $F_1(1, 92) =$

139.30, $p < .001$, $MSE = 1{,}967.4$. This reduction of the priming effect with the lengthening of the ISI was, however, not completely reliable; it was significant when analyzed by students but not when analyzed by item. No other interaction involving prime type was significant. This means that the facilitatory effect found between words overlapping from the end was not affected by the prime–target frequency relation or by the task.

In regard to error rates, the main effect of ISI was significant, $F_1(1, 184) = 11.32$, $p < .001$, $MSE = 1.1$; $F_2(1, 60) = 22.75$, $p < .001$, $MSE = 0.8$, and did not interact significantly with any other variable. Errors were more numerous with the short than with the long ISI. The other significant main effects were those of task $F_1(1, 184) = 201.34$, $p < .001$, $MSE = 1.1$; $F_2(1, 60) = 41.19$, $p < .001$, $MSE = 8.3$, and frequency, $F_1(1, 184) = 78.83$, $p < .001$, $MSE = 1.1$; $F_2(1, 60) = 12.31$, $p < .001$, $MSE = 10.2$. The Task × Frequency interaction was also significant, $F_1(1, 184) = 124.02$, $p < .001$, $MSE = 1.1$; $F_2(1, 60) = 21.83$, $p < .001$, $MSE = 8.3$. This was due to the frequency effect being different in size and direction but significant with both the lexical decision task, $F_1(1, 92) = 113.38$, $p < .001$, $MSE = 1.9$; $F_2(1, 60) = 16.88$, $p < .001$, $MSE = 18.01$, and the shadowing task, $F_1(1, 92) = 11.89$, $p < .001$, $MSE = 0.3$; $F_2(1, 60) = 5.73$, $p < .025$, $MSE = 0.5$.

As noted in the *Method* section of Experiment 1, the durations of the words were different in the four groups of words. High-frequency words were, on average, 30 ms longer than low-frequency ones in the beginning overlap set and 12 ms shorter in the final set. The words of the beginning set were shorter than those of the final set (the differences were 31 ms and 73 ms for low-frequency and high-frequency words, respectively). When RTs were corrected for word length, the difference between high- and low-frequency words was reduced (the frequency effect being greater in the beginning set). For control trials, the frequency effects in the beginning set and the late set, respectively, were 193 ms and 139 ms in Experiment 1, 45 ms and 50 ms in Experiment 2, 180 ms and 143 ms in Experiment 3, and 5 ms and 30 ms in Experiment 4.

Although the differences in the durations of the four groups of words were not significant, we reanalyzed the data taking word duration into account. RTs were corrected for stimulus duration by subtracting the duration of each item from the RT for the item. ANOVAs with the same five variables described earlier were run on RTs by student and by item. These analyses obviously could not change the effects of variables other than frequency and overlap or their interaction. Overlap was again significant by students, $F_1(1, 184) = 87.11$, $p < .001$, $MSE = 2{,}607.8$, but not by item (an F_2 value close to 1). Regarding frequency, the effect was a little smaller but still highly significant in both analyses, $F_1(1, 184) = 53.97$, $p < .001$, $MSE = 33{,}998.3$; $F_2(1, 60) = 15.74$, $p < .001$, $MSE = 78{,}894.6$. The Frequency × Overlap interaction, which in the previous analyses was significant by student but not by item, ceased here to be significant even by student ($F_1 < 1$). There were no other differences between the two kinds of analyses.

Our material involved, as critical items, pairs of words with a CVC structure in most of the cases. However, in some cases the words had a CCV structure. This occurred, in particular, in 3 of the 16 pairs of the set with final overlap. Although the priming effect was significant not only by students but also by item, which indicates a limited variability among items, differences in the effects obtained with the two kinds of words might have been hidden by the small number of CCV words. We thus calculated the priming effects separately for the words of each structure in the final overlap condition. The effects were not very different from one structure to the other. For Experiments 1 to 4, respectively, the mean effects, averaged for the two frequency conditions, were 98 ms, 60 ms, 66 ms, and 26 ms for the items with a CVC structure and 72 ms, 61 ms, 36 ms, and 51 ms for the items with a CCV structure. It thus seems that the amount of priming is not restricted to a particular phonological structure.

General Discussion

The main purposes of the present research were (a) to compare phonological priming between auditorily presented pairs of three-phoneme monosyllabic words with beginning and final overlap of two phonemes and (b) to ascertain whether and how these effects are modulated by the high–low or the low–high frequency relation between prime and target. Both the lexical decision task and the shadowing task were used, each with a short (20 ms) and a long (500 ms) ISI. The basic finding was that facilitation consistently occurred between words overlapping from the end. This facilitatory effect was reduced when the ISI was increased from 20 ms to 500 ms, suggesting that the effect is relatively immune to bias. When the overlapping phonemes were aligned from onset, no significant effect was found in any of the frequency conditions of the experiments using the lexical decision task. However, a small tendency toward inhibition, although not completely reliable (i.e., not significant in the analysis by item), was found in the low–high frequency condition of the experiment using the shadowing task and a short ISI.

These results should now be compared with relevant findings in the literature. We begin with initial overlap. When studies using the lexical decision task are considered, initial overlap generally gives rise to no effect. The lack of effect of initial overlap in the present study is consistent with the data reported by Slowiaczek and Pisoni (1986), Goldinger et al. (1992), and Burton (1992). As noted in the introduction, the complex pattern of results found by Radeau et al. (1989), which included facilitation, inhibition, or no effect depending on whether the primes or the targets were words or pseudowords, was interpreted in terms of decision biases.

Conversely, in studies using the shadowing task, inhibitory effects were found by Slowiaczek and Hamburger (1992, 1993) for monosyllabic items overlapping by three phonemes. They were also reported by Radeau et al. (1989, Experiment 1), who used disyllabic items sharing two phonemes (corresponding to the first syllable) and word primes, a condition that was also met in the two studies just cited (Slowiaczek & Hamburger, 1992, 1993) and in the present experiments. With pseudoword primes, initial overlap of one to three phonemes did not give rise to any effect (Radeau et al., 1989, Experiment 2). Note, however, that, using word primes, Burton (1992, Experiment 3) failed to find an effect of first syllable overlap (two or three shared phonemes) between disyllabic items.

Thus, initial overlap of more than one phoneme between a word prime and a target sometimes gives rise to inhibition when shadowing is used as the task. The likelihood that the effect will reach significance may depend on the number of shared initial phonemes. Inhibition was more consistently found with overlap of three phonemes than with overlap of two phonemes. For two-phoneme overlap, Slowiaczek and Hamburger (1992, 1993) reported either no effect or facilitation. It is thus especially interesting that we obtained a small inhibition effect in one of the conditions of the present experiments. Slowiaczek and Hamburger (1992) proposed that the inhibitory effect of initial overlap would result from competition between neighbors at the lexical level. This conclusion was based both on obtaining of cross-modal priming and on lack of pseudoword priming. We speculate that the present trend toward interference is lexical because it was affected by prime–target relative frequency. In agreement with the predictions of the NAM model and with the results of Goldinger et al. (1989) in phonetic priming, it was found only in the low–high frequency condition.

Although we agree with the view that inhibition may reflect lexical processing and not always response bias, the contradictory pattern of results found in studies on initial overlap using the lexical decision task (especially the lack of consistency between the shadowing and lexical decision studies) remains very difficult to explain other than in terms of strategies. As Goldinger et al. (1992) and, recently, Slowiaczek and Hamburger (1993) have demonstrated, strategic priming is a frequent outcome in phonological priming studies.

The effect of final overlap has been examined less frequently than the effect of initial overlap. Fortunately, the consistency in the results is striking. With disyllabic words and pseudowords, Emmorey (1989) found facilitatory effects, except when the shared final part was a suffix. Using disyllables and monosyllables, respectively, Burton (1992) and Burton et al. (1993) always found facilitatory effects. Corina (1992) also consistently found facilitation for final overlap (either the syllable in disyllabic words or the rime in monosyllabic CVC words). Our results provide converging evidence for the facilitatory effect of final overlap.

Obtaining facilitation in the final overlap condition is no more compatible with the NAM model than with the cohort model. This, however, does not necessarily invalidate the models. Indeed, it may be that the final overlap effect does not take place at the lexical level but taps earlier stages of processing. Supporting this view, the effect appeared to be insensitive both to the frequency of the target and to the frequency relationship between prime and target. If it is likely that word recognition processes that are influenced by word frequency take place at (or after) the lexical level, it is tempting to assume that processes that are not influenced by word frequency take place earlier in the processing flow than at the lexical level. However, the lack of a prime–target relative frequency effect is not a compelling argument against lexical involvement. As suggested by Marslen-Wilson (1990), rapid dissipation of activation or inhibition may prevent any effect from being manifest. Insensitivity of the final overlap priming effect to prime–target relative frequency might thus indicate postlexical as well as prelexical involvement.

However, other data that we have recently discovered argue more convincingly for a prelexical locus of the final overlap priming effect. These data come from a two-step study analogous in rationale to that performed by Slowiaczek and Hamburger (1992) to assess the locus of their effects. The first step consisted of using a cross-modal priming technique, and the second consisted of estimating the effect of pseudoword primes. The idea underlying the cross-modal study was that a priming effect arising at the lexical level should be of comparable size when tested within or across different modalities. On the contrary, an effect located at a stage earlier than the lexicon should not transfer across modalities. Using the lexical decision task and the materials of the present low–high frequency condition, we failed to obtain a facilitatory effect of final overlap using a cross-modal technique with an auditory prime and a visual target (Radeau, Segui, & Morais, 1994). Lack of effect in these presentation conditions supports the view that the effect observed here is prelexical.

Slowiaczek and Hamburger (1992), as mentioned, also compared the effect obtained with word and pseudoword primes as well (see also Radeau et al., 1994). If the facilitatory effect found for final overlap were lexical, it should be greater for word primes than for pseudoword primes. Indeed, because pseudowords are not stored in the lexicon, they should yield much less lexical activation than word primes. The items, all with a consonant–consonant–vowel–consonant structure, were presented auditorily, and the task was shadowing. A facilitatory effect of shared rime was found, and it was not significantly affected by the lexical status of the prime. The evidence that the facilitatory effect of final overlap is modality specific, together with the obtaining of an effect similar in size with word and pseudoword primes, thus suggests that this effect occurs at a prelexical level of representation.

The fact that the facilitatory effect of final overlap is both strong and reliable constitutes an invitation for the current theorizing of spoken word recognition to pay more attention to the role of prelexical processes than has been the case in the models mentioned here. Thus, further work on this effect may be worthwhile. In this context, the structure of the prelexical representations involved in the facilitatory priming effect is a significant issue. Although most authors usually refer to phonemes, larger units might be involved in phonetic or phonological priming effects, possibly depending on language. An interesting characteristic of the overlap between prime and target used in the final overlap condition of the present experiments is that it either corresponded to the rime (the VC part of CVC items) or included the rime (the CV part of CCV items). Thus, the final overlap priming effect observed here may be actually a rime priming effect. Another possibility is that it depends crucially on the vowel, which is the segment with the highest energy in the syllable. However, the present study provides a strong indication that integrity of the rime is necessary for the facilitatory priming effect to occur. Indeed, in the initial overlap condition, the vowel was common to prime and target, and no priming effect occurred. An alternative but less likely interpretation is that only sharing of the last phoneme is critical. We are currently testing this issue.

Whether or not the final overlap priming effect results from the prime and target sharing the rime, one may wonder why final overlap is more effective than same-length initial overlap in eliciting phonological priming. At first sight, the present finding may appear counterintuitive, because initial parts of the signal are often assumed to be of critical importance for identification. However, at least two possible mechanisms might be considered.

One of them would be compatible with the general framework of the cohort model. According to this approach, the initial sounds of the target activate a set of candidates that are matched from the onset with the input. Additional activation from initial overlap priming, if there is any, would be insufficient to allow the listener to recognize the target word. However, activation from a previously presented prime sharing the final sounds with the target would allow one of the lexical candidates to be more quickly selected than if there were no such priming. The final overlap priming effect would thus occur at the lexical selection phase rather than when the cohort is activated. This interpretation is consistent with the fact that the observed final overlap effect is independent of the lexical status of the prime. In contrast, if the crucial role is assigned to lexical selection, no facilitation for pseudoword targets is predicted.

An alternative interpretation of the final overlap effect that would be compatible with effects obtained for both word and pseudoword targets is based on the hypothesis of a delay between onset of the successive constituents of the target (to remain neutral in terms of the nature of the units involved, we term them *sounds*) and onset of their processing. Suppose that identification of the initial sounds of the target starts immediately at their onset and that this process is still not finished when the final sounds are presented. This temporal gap might have a negative impact on the identification of the final sounds. Priming final sounds might thus compensate for their relative disadvantage, whereas priming initial sounds would be useless. This interpretation leads to the prediction that the final overlap priming effect would be reduced by decreasing the target's articulation rate. We plan to check both of these interpretations.

References

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 340–357.

Bard, E. G., Shillcock, R. C., & Altmann, G. T. M. (1988). The recognition of words after their acoustic offsets in spontaneous speech: Effects of subsequent context. *Perception and Psychophysics, 44,* 395–408.

Burton, M. W. (1992, November). *Syllable priming in auditory word recognition.* Poster session presented at the 33rd annual meeting of the Psychonomic Society, St. Louis, MO.

Burton, M. W., Jongman, A., & Sereno, J. (1993, November). *Phonological and orthographic priming effect in auditory and visual word recognition.* Poster session presented at the 34th annual meeting of the Psychonomic Society, Washington, DC.

Colombo, L. (1986). Activation and inhibition with orthographically similar words. *Journal of Experimental Psychology: Human Perception and Performance, 12,* 226–234.

Coltheart, M., Davelaar, E., Jonasson, J. Y., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). London: Academic Press.

Connine, C. M., Mullennix, J., Shernoff, E., & Yelen, J. (1990). Word familiarity and frequency in visual and auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 1084–1096.

Content, A., Mousty, P., & Radeau, M. (1990). BRULEX: Une base de données lexicales informatisée pour le français écrit et parlé [Brulex: A computerized lexical database for written and spoken French]. *L'Année Psychologique, 90,* 551–566.

Corina, D. P. (1992). Syllable priming and lexical representations: Evidence from experiments and simulations. In *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society* (pp. 779–784). Bloomington: Indiana University.

Emmorey, K. D. (1989). Auditory morphological priming in the lexicon. *Language and Cognitive Processes, 4,* 73–92.

Goldinger, S. D., Luce, P. A., & Pisoni, D. B. (1989). Priming lexical neighbors of spoken words: Effects of competition and inhibition. *Journal of Memory and Language, 28,* 501–518.

Goldinger, S. D., Luce, P. A., Pisoni, D. B., & Marcario, J. K. (1992). Form-based priming in spoken word recognition: The roles of competition and bias. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1211–1238.

Grosjean, F. (1985). The recognition of words after their acoustic offset: Evidence and implications. *Perception and Psychophysics, 38,* 299–310.

Imbs, P. (1971). *Trésor de la langue Française. Dictionnaire des fréquences* (French language frequency counts). Paris: Klincksieck.

Jakimik, J., Cole, R. A., & Rudnicky, A. I. (1985). Sound and spelling in spoken word recognition. *Journal of Memory and Language, 24,* 165–178.

Luce, P. A. (1986). *Neighborhoods of words in the mental lexicon.* Unpublished doctoral dissertation, Indiana University, Bloomington.

Luce, P. A., Pisoni, D. B., & Goldinger, S. D. (1990). Similarity neighborhoods of spoken words. In G. T. Altmann (Ed.), *Cognitive models of speech processing: Psycholinguistic and computational perspectives* (pp. 122–147). Cambridge, MA: MIT Press.

Marslen-Wilson, W. D. (1985). Speech shadowing and speech comprehension. *Speech Communication, 4,* 55–73.

Marslen-Wilson, W. D. (1987). Functional parallelism in spoken word-recognition. *Cognition, 25,* 71–102.

Marslen-Wilson, W. D. (1990). Activation, competition, and frequency in lexical access. In G. T. Altmann (Ed.), *Cognitive* *models of speech processing: Psycholinguistic and computational perspectives* (pp. 148–172). Cambridge, MA: MIT Press.

Marslen-Wilson, W. D., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognitive Psychology, 10,* 29–63.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology, 18,* 1–86.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 108,* 226–254.

Norris, D. (1986). Word recognition: Context effects without priming. *Cognition, 22,* 93–136.

Posner, M. I., & Snyder, C. R. (1975). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55–85). Hillsdale, NJ: Erlbaum.

Radeau, M., Morais, J., & Dewier, A. (1989). Phonological priming in spoken word recognition: Task effects. *Memory & Cognition, 17,* 525–535.

Radeau, M., Segui, J., & Morais, J. (1994). The effect of overlap position in phonological priming between spoken words. In *Proceedings of 1994 International Conference on Spoken Language Processing* (Vol 3, pp. 1419–1422). Yokohama, Japan: The Acoustical Society of Japan.

Slowiaczek, L. M. (1994). Semantic priming in a single-word shadowing task. *American Journal of Psychology, 107,* 245–260.

Slowiaczek, L. M., & Hamburger, M. B. (1992). Prelexical facilitation and lexical interference in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1239–1250.

Slowiaczek, L. M., & Hamburger, M. B. (1993, November). *Phonological priming in spoken word recognition is not strategic.* Paper presented at the 34th annual meeting of the Psychonomic Society, Washington, DC.

Slowiaczek, L. M., Nusbaum, H. C., & Pisoni, D. B. (1987). Phonological priming in auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 64–75.

Slowiaczek, L. M., & Pisoni, D. B. (1986). Effects of phonological similarity on priming in auditory lexical decision. *Memory & Cognition, 14,* 230–237.

Appendix A

Summary of the Main Phonological Priming Studies

	Condition			Results	
Study	Prime	Target	ISI	Initial overlap	Final overlap
Slowiaczek & Pisoni (1986)					
Experiment 1 (LD)	1 syll. W+P	1 syll. W+P (no controls)	500 (or 50)	1, 2, 3 ph.: not different	
Experiment 2 (LD)	1 syll. W+P	1 syll. W+P	50	1, 3 ph.: no effect	
Slowiaczek et al. (1987)					
Experiment 1 (IN)	1 syll. W	1 syll. W	50	1 ph.: no effect 2, 3 ph.: Fac.	
Experiment 2 (IN)	1 syll. P	1 syll. W	50	1, 2 ph.: no effect; 3 ph.: Fac.	
Radeau et al. (1989)					
Experiment 1 (LD and shadowing)	2 syll. W	2 syll. W+P	(SOA = 700)		
W					
1 ph.				No effect	
2 ph. (1 syll.)				Inh.	
P					
1, 2 ph. (1 syll.)				No effect	
Experiment 2 (LD and shadowing)	2 syll. P	2 syll. W+P	(SOA = 850)		
W					
1, 2 ph. (1 syll.)				No effect	
3 ph.				LD: Fac.; shadowing: no effect	
P					
1 ph.				No effect	
2 (1 syll.), 3 ph.				LD: Inh.; shadowing: no effect	

(*Appendix A continues on next page*)

Appendix A (continued)

Study	Condition			Results	
	Prime	Target	ISI	Initial overlap	Final overlap
Goldinger et al. (1992)					
Experiment 1 (IN)	1 syll. W	1 syll. W (50% Rel. trials)	50	1 ph.: Fac.	
Experiment 2 (IN)	1 syll. W	1 syll. W (10% Rel. trials)	50	1 ph.: no effect	
Experiments 3 and 4 (LD)	1 syll. W	1 syll. W+P (50% Rel. trials)	50, 500, or 1,500		
		In white noise		1 ph.: Fac.	
		In the clear		1 ph.: no effect	
Experiment 5 (LD)	1 syll. W	1 syll. W+P in white noise (10% Rel. trials)	50	1 ph.: Inh.	
			500	1 ph.: no effect	
Slowiaczek & Hamburger (1992)					
Experiments 1A, 2A (shadowing)	1 syll. W	1 syll. W	500	1 ph.: Fac.; 2 ph.: not different from 1 ph.; 3 ph.: slower than 1 ph.	
Experiment 3A (shadowing)	1 syll. P	1 syll. W	500	1 ph.: Fac.; 2 ph.: not different from 1 ph.; 3 ph.: not different from 1 ph.	
Slowiaczek & Hamburger (1993)					
Shadowing	1 syll. W	1 syll. W (20% or 80% Rel. trials, repetitions)	50 or 500	1 ph.: no effect; 2 ph.: Fac.; 3 ph.: Inh.	
Shadowing	1 syll. W	1 syll. W (20% Rel. trials, no repetition)	50	1 ph.: no effect; 2 ph.: no effect; 3 ph.: Inh.	
Slowiaczek et al. (1987)					
Experiment 3 (IN)	1 syll. W	1 syll. W	50		1 ph.: no effect; 2, 3 ph.: Fac.
Emmorey (1989)					
Experiment 1 (LD)	2 syll. W (weak–strong)	2 syll. W+P (weak–strong)	50		Morpheme: Fac.; at least 1 syll.; no effect
Experiment 2 (LD)	2 syll. W (strong–weak)	2 syll. W+P (strong–weak)	50		1 syll.: Fac.
Experiment 3 (LD)	2 syll. W (strong–weak)	2 syll. W (strong–weak)	50		1 syll.: Fac. Suffix: no effect
Burton et al. (1993)					
LD + shadowing	1 syll. W	1 syll. W+P	50		Rime: Fac.
Burton (1992)					
Experiment 1 (LD)	2 syll. W	2 syll. W+P	50	1 syll.: no effect	1 syll.: Fac.
Experiment 2 (LD)	2 syll. W	2 syll. W+P	50		1 syll.: Fac. Rime: Fac.
Experiment 3 (shadowing)	2 syll. W	2 syll. W	50	1 syll.: no effect	1 syll.: Fac.
Corina (1992)					
Experiment 1 (LD)	2 syll. W	2 syll. W+P	100	1 syll.: Fac.; 3 ph.: no effect	1 syll.: Fac.
	1 syll. W	1 syll. W+P		3 ph.: Fac.	
Experiment 2 (LD)	1 syll. W	1 syll. W+P		2 ph.: no effect	2 ph.: Fac.

Note. ISI = interstimulus interval; LD = lexical decision; syll. = syllable; W = words; P = pseudowords; ph. = phoneme; IN = identification in noise; Fac. = facilitation; SOA = stimulus onset asynchrony; Inh. = inhibition; Rel. = related.

Appendix B

Words Used as Related and Control Items

Beginning overlap			Final overlap		
Related pairs			Related pairs		
Low frequency	High frequency	Control words	Low frequency	High frequency	Control words
bouc	boule	meute	douche	bouche	latte
cône	côte	lime	bave	cave	rire
digue	dix	râle	came	dame	ruche
douille	doute	sauce	bure	cure	songe
gaffe	gare	mine	tonne	bonne	loupe
gousse	goutte	lame	beigne	peigne	race
pote	poche	rêve	bache	tache	nord
pouf	pouce	nuque	bêche	pêche	note
pif	pipe	nerf	cotte	botte	jour
teck	terre	niche	caille	paille	noce
tif	tige	monde	dague	bague	juge
tonte	tombe	foule	poupe	coupe	zone
bru	bras	ligue	panse	danse	mule
clos	clou	fève	drain	train	fugue
croc	creux	vif	tri	cri	lutte
proue	prix	fard	crin	brin	legs

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